CircBoost

PILOT YEAR 1 REPORT

Funded by
the European Union

Document Information

Grant Agreement Number		101082068	Acronym	CIRC-BOOST
Full Title	Boosting the uptake of circular integrated solutions in construction value chains			
Start Date	1st June 2023	**Duration**	48 months	
Project URL	www.circboostproject.eu			
Milestone	N/A			
Work Package	WP3 – PILOT			
Date of Delivery	**Contractual**	30/11/2023	**Actual**	29/11/2023
Nature	R – document, report	**Dissemination Level**	PU – public	
Lead Beneficiary	FCE			
Responsible Author	Ivan Ignjatović, FCE			
Contributions From	UPC; SEN; TESIS; CAP; FCE; UiT; MNORD; SKANSKA			

Document History

Version	Issue Date	Stage	Description	Contributor
1	31/10/2024	1st draft	Table of Content	UPC; SEN; TESIS; CAP; FCE; UiT MNORD; SKANSKA
2	25/11/2023	2st draft	First incomplete draft	UPC; SEN; TESIS; CAP; FCE; UiT MNORD; SKANSKA
3	27/11/2023	3st draft	First complete draft	UPC; SEN; TESIS; CAP; FCE; UiT MNORD; SKANSKA
4	29/11/2023	Revision	Final document	UPC; SEN; TESIS; CAP; FCE; UiT MNORD; SKANSKA
5	07/01/2025	Revision	Revised document	FCE
6	04/04/2025	Revision 01	Revised according to EC reviewer's comments	UPC; SEN; TESIS; CAP; FCE; UiT MNORD; SKANSKA

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Table of Contents

Table of Figures

Table of Tables

List of abbreviations

ACC	Acciona Construcción
BIM	Building Information Modeling
CAP	Cap Digital
CDE	Control Demeter
CDW	Construction and demolition waste
CSTB	Centre Scientifique et Technique du Bâtiment
CVUT	Czech university of technology (from CZ “České vysoké učení technické”)
DfD/R	Design for deconstruction and reuse
EC	European Commission
EIGD	Eiffage
GA	Grant Agreement
GPA	Greater Paris Area
KPI	Key Performance indicators
LCA	Life-Cycle Assessment
LCC	Low carbon concrete
LoD	Level of detail
LUA	Lundhagem architects
MCDM	Multi-Criteria Decision-Making
MGP	Metropole du Grand Paris
MNORD	Museum Nord
MOCU	Modransky Sugar Factory from CZ “Modřanský cukrovar”
NAC	Natural Aggregate Concrete
NBS	Nature Based Solutions
NFC	Near-field communication
NGE	Nouvelles Générations d’Entrepreuneurs
PDS	Pilot Deployment Strategy
PEMD	Produits, Equipements, Matériaux et Déchets
POC	Proof Of Concept
POP	Pilot Operational Plan
RA	Recycled Aggregate
RCA	Recycled Concrete Aggregate
RAC	Recycled Aggregate Concrete
RENO	Reno-vest
RFID	Radio Frequency Identification
SEN	Smart Engineering
SI	Sustainability Index
SIT	Sitowie
UGE	University Gustave Eiffel
UiT	UIT The Arctic University of Norway
UPC	Universitat Politècnica de Catalunya
WP	Work Package

RESPONSES ON REVIEWER'S COMMENTS

	Comments	*PNo	Section**	Summary of response***
1	Comments for consideration. Some of these are mere matters of form and thus not very important, as the report is not public. However, some significantly weaken the readability. As a minor comment, some important abbreviations are missing from the list of explanations: For example DfD/R (Design for deconstruction and reuse), RFID (Radio Frequency Identification). PEMD is only explained in French. There are several notes "(Error! Reference source not found.)" (more than 20).	WP3		Abbreviations have been put in the list. Text in French has been translated into English. Errors related to the figures numbering are corrected.
2	Recommendation: According to the project plan and DoA, the progress of the pilot are reported yearly with the help of the specific pilot reports. These reports are not public. The first progress report - Pilot Year 1 Report — includes a lot of and quite detailed information about the performed work. Thus, the report is useful from the viewpoint of reviewing and verifying that all planned tasks have been done. However, at the same time, the report is also somehow overlapping with the technical report. In addition, this kind of form may not be useful for the consortium itself. The recommendation is to change the character of the report in order to be less about doings and much more about interim results and their analysis to best support and direct the work in coming months/ years.	WP3		Thank you for recommendation. For the next reporting period (M19-M30), we will change the character of Technical report compared to Pilot Year 2 report.
3	There are several typos on page 18 (Pilot 1). On page 14 (T.3.3.3) (Pilot 1) it is said that "the point cloud scanning of the excavated material was carried out and the generated point clouds were successfully converted to BIM objects. " **Please**	1	3.1.1.1, 3.1.1.2	Typos detected on page 18 have been corrected. An explanation of the relation between Circ-Boost and LaMercedes was added, as well

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	clarify the connection to the LaMercedes plant and please explain the stage of the corresponding work related to other materials than excavated materials regarding the target to use of BIM-based digital twins for the generation of material and element databanks and stocks for reuse and recycling.			as an update regarding other on-site works (waiting construction permits to enable access).
4	On page 17 (T3.3.5 and T3.3.6), (Pilot 1) it is said that "the objective of this line within Pilot 1 is the development of a modular DfD/R precast concrete panel system, the execution of a pilot structure, its testing under loads, dismantling and second construction". **Please explain the connection of this task with the laMercedes plant pilot (if any).**	1	3.1.2	A clarification has been added on page 18.
5	Regarding Pilot 2, according to the report (page 28) "A first important step regarding Platform governance was of a political nature: we needed to ensure the political approval of the transfer of management of the platform project from Plaine Commune to MGP. This transfer, as well as the transfer of Plaine Commune initial actions in CIRCBOOST, has been validated by elected representative." **Possibly because of this change of partner, some parts of the document regarding Pilot 2 remain somewhat unclear.** According to the report (Pilot 2, page 24) "Two sites for the digital platform have been identified: an inert and soil waste streams management site (1) and a fixture products reconditioning site (2)". **Please clarify the meaning:** Is this a final idea for the digital platform or do these two sites present only the starting point for the development. According to the DoA "The digital tool to be developed should make it possible to better visualize all the available deposits on a territory (mapping of materials) in real time, by consolidating information which are currently very diffuse. The materials concerned can come from buildings (concrete, wood, finishing materials, etc.) as well as public	2	3.2.1	Page 24: Two sites for the physical platform have been identified: an inert and soil waste streams management site (1) and a fixture products reconditioning site (2). This represents the starting point of the pilot deployment regarding the identification of physical platformswhich will then be interconnected with the digital platform, as well as with other existing or future physical platforms located within the territory of the MGP. As specified in the POP, the aim of the digital tool is to aggregate all materials deposits in the region, and therefore to make visible data from a variety of sources: online marketplaces, online catalogs of physical platforms, public platforms; as well as materials offers and requests put online directly by users. The platform covers all building products, equipment and materials, as well as certain exterior materials (pavers, kerbs, etc.).

	spaces (paving stones, kerbs, earth, etc)." On the basis of the DoA, the idea of the platform is not limited to soil waste streams and fixture products, but the intended coverage of the platform is more extensive.			
6	According D3.2 (page 33, Pilot 2) "The methodology proposed a state of the art of models of all urban metabolism, water use, transportation, mobility needed in a suburban area... The report can be found in Annex 2". However, the **Annex 2 is missing**. Please add the Annex 2. (or is it going to be added in the later completed version year 2 or 3 report?).	2	3.2.2	Annex 2 translated in English and available as a part of D3.2
7	To make the LCA results meaningful, it is important to make comparative studies. **Please explain what the basis of comparison is. Please also discuss the methodological approach regarding service life and durability** especially if the use of disassembled products could influence the remaining lifetime.	2	3.3.6	Page 36 to 37: UGE / COSYS : State of the art and reassessment of the environmental evaluation of experimental Eco construction site (E3S, situated in the suburban areas of Paris). The research programme is structured around the following themes: • Methodology for quantifying construction and public works flows • Evaluation and monitoring of circular economy strategies • Evaluation of solutions on real construction site cases, from an environmental point of view, using ISO 14001, • Prospective of the circular economy based on the construction of scenarios (construction variants using structural existing parts, more or less recycled concrete aggregate…. This work contributes to understanding the challenges of the circular economy, including the

				mobilization of waste as a resource, transportation, as well as the storage and treatment of waste from deconstruction projects. Although environmental assessment is highly standardized, predicting impact scores when proposing alternatives remains difficult, and the significance of various construction choices is still not well understood. We studied an existing deconstruction-reconstruction site than has been used as a research case since the deconstruction phase (E3S). It has now become a living urban area. The study has been carried out using complete life cycle analysis integrating the deconstruction phases, the management of excavated material and resources and their mobilization within the project (based on real dataset). At each phase, possible variants must be evaluated on the basis of the ISO 1400 standard. For example, the following aspects could be considered: reducing the amount of reinforcement and adjusting concrete formulations, using recycled concrete aggregates and reusing reusable structural elements such as slabs, columns and wood. The lifespan of theses solutions, including their intended use and the duration of the operation (including maintenance) will also be an integral part of the assessment, even though lifespan considerations are not currently regulated. The objective of this work is to adopt an approach that prioritizes

				environmental impact over other criteria, particularly project cost. Fictitious alternative (reconstruction) scenarios can therefore be developed and evaluated. Several existing environmental assessment software programs can also be used and compared as part of this study (including an in-house program and OpenLCA). The identification of the materials database used on this experimental construction site was conducted, using DIOGEN-CIOGEN database (from AFGC “Association Français de Génie Civil”) and INIES. The report serves as an application of standards and the state of the art, specifically applied to E3S and proposes: - Modelling environmental impact using LCA tools for construction phases and material choices, comparing conventional construction with an experimental building maximizing recycled concrete materials, and evaluating alternative reuse-based scenarios. - Comprehensive environemental impact analysis considering life span of buildings (40 years), - State of the art research aimed at providing a comprehensive analysis of the spatial dynamics of these urban areas up to 2050 and beyond. This includes models of various factors influencing urban environmental impacts, as well as the evaluation of urban transportation, urban metabolism and key characteristics of dense areas.

				The report can be found in Annex 2. All these approaches will feed a forecasted urban dynamic model to evaluate environmental impacts of urban areas, including carbon footprint. This will be developed in next step related to the platform deployment. Research activities will later focus on the methodology for environmental evaluation using Life Cycle Analysis open tools (OpenLCA) and propose optimization mathematical tools to assess socio-economic and environmental impacts over a 40-year lifespan in dense urban areas. It will focus on the specific cases of the physical platforms. This advanced modelling will primarily focus on urban mobility, maintenance of buidings (for various scenarios), and urban metabolism, including water. The research is ongoing with completion expected by the end of 2025.
8	Table 3.2-1 - Pilot 2 Milestones defines high values for the percentage of fulfillment such as 100 % for Milestones "Axe 1: Characterization of materials and ways of reuse - Milestone 1" and "Axe 3: Environmental impact using indicators - State of the art". **However, this is not compatible with the fact that for example Annex 2 is missing.**	2	Annex 2	Annex 2 translated in English and available soon
9	According to the report (Pilot 2, page 24) "A innovative start-up (Skop) has been selected to develop the prototype platform through a BPI (Public Investment Bank) call for projects." Please explain the relation of BPI funded project and Skop with CIRCBOOST. **Please also explain the real starting point for the development of the digital**	2		Page 24-25: As specified in paragraph 5.4.2 of D3.1: In parallel of the CIRCBOOST project, Plaine Commune, a territory of Metropole du Grand Paris is leading the development of a POC - Proof of concept - with the start-up SKOP, within an “AI

	platform. Is there an existing proof of concept (POC) or digital platform that CIRCBOOST is further developing or is the project truly making a new development.			challenge" launched by the French Public Investment Bank "BPI" and won by Plaine Commune. The main goal of this POC is to develop and test the following functionalities that have been identified as a priority by Plaine Commune focus on the "territory oriented": • Matchmaking tool: Centralize online all the information concerning reuse material available - wherever the data about these materials is (marketplaces, online catalogues of physical platforms, public platform, ...). Plaine Commune also already owns a lot of data / information, thanks to a data basis that groups all the information about available resources and material needs: ; that will be used to test SKOP digital platform. • Centralize online, on the same digital platform, all the information about needs of reused materials, to enable automatic matchmaking between available and researched reuse materials. All users that look for materials might be able to receive regular updates as soon as a new reuse material that matches their needs is entered in the digital platform • Map all this information on a chart, to be able to visualize all the future projects and localize the nearest reuse materials During CIRCBOOST project, the goal is to is to build on the work accomplished during the POC and continue to develop the platform by adding innovative

				functionalities. This development will be based on 3 functionalities) • Matchmaking platform: Centralize in a digital platform (interoperable meta-platform) all the materials / resources available and demands of reuse and recycled materials and automate a match-making between them • Indicators calculation: Assess the actions thanks to practical indicators (environmental impact, impact on transportation, jobs created, potential for reuse and recycling, etc.) • Prediction of flows: Analyze and predict materials and waste flows Following the completion of the POC (end of March 2025), a first prototype digital platform is now available, fulfilling the functionalities described above. In order to capitalize on this work, the Metropole has decided to pursue the development of the tool with the same company (SKOP). The contract with SKOP, via an 18 months public innovation contract, will enable the tool to be deployed in the territories, improve existing functionalities and develop new ones.
10	According to the report (Pilot 2, page 28) "CSTB tested the POC after credentials have been shared by MGP to evaluate certain needs or attention points related to the connection of the POC to PEMD platform and to the prediction functionality related to CSTB urban mining tool BTPFlux." **Please explain the role and relation of PEMD with the project.**	2	3.2.2	Page 30-31: CSTB tested the POC after credentials have been shared by MGP to evaluate certain needs or attention points related to the connection of the POC to PEMD platform and to the prediction functionality related to CSTB urban mining tool BTPFlux. The PEMD platform collects all the regulatory diagnoses carried out by developers of demolition and renovation projects subject to the regulations. It enables them to

				identify specific types of waste suitable for reuse. A connection between BTP Match and this platform would provide an additional data source for displaying reusable materials offers. Another potential integration involves the provision of consolidated regional statistics. CSTB is currently analyzing data from all submitted diagnoses to generate statistics such as the most commonly reused materials and their respective quantities. This information could be shared with territories using BTP Match to enhance their dashboards. As regards the link between the PEMD platform and the BTP Flux tool, BTP Flux already predicts outflows and inflows of materials in a given area. Connecting the PEMD tool with BTP Flux would make it possible to add the “reuse” variable: outgoing flows of reusable materials and incoming reused materials. Once connected to BTP Match, this module could forecast the supply of materials from upcoming deconstruction/renovation projects and anticipate future reuse needs.
1 1	~~The text in the following figures (Pilot 2) is not readable: Figure 3.1-11 (Protocol for information storage), Figure 3.1-18 (Design checks for the prototype structure)~~ Figure 3.2-2 (Definition of digital platform functions, Pilot 2) includes a lot of (obviously important!) text but only in French. Figure 3.2-3 (First feedback from POC users, Pilot 2) also includes information but only in French. The heading of the Figure 3.2-1 is "Role of the digital platform: facilitating the matching of reused materials". However, the screenshot of the Figure 3.2-5 (Screenshot of the POC digital	2		Page 26 to 32: All figures translated in English. Regarding Figure 3.2-5: NB: The platform covers all products, materials and equipment for the building industry (finishing materials), as well as certain materials specific to the development of public spaces (bricks, pavers, concrete slabs, etc.).

	platform (category selection)) presents different kinds of lamps. **Please clarify what is the focus with reference to the original idea that the materials concerned can come from buildings (concrete, wood, finishing materials, etc.) as well as public spaces. Figures 3.2-6 (Validation of digital platform governance (steering committee)) and 3.2-7 (Long-term economic and governance scenarios) should be translated into English.**			
12	According to D3.2 (Page 32, Pilot 2), "This task has not really been started as the POC is still going on. Additional financing needed to develop final Digital Platform is starting to be investigated." **Please provide some information to clarify the reasons for the need of additional financing. Please also clarify whether this causes a risk for the project.** According to D3.2 (page 32, Pilot 2) "A 6 internship worked on platforms design and platforms visits (GERS) and delivered a report (MS27) that can be found in Annex 1." However, the Annex is missing. Please add the Annex 1 (or is it going to be added in the later completed version year 2 or 3 report?).	2	3.2.2	1st part, page 34 to 35: The funding allocated to the Metropole du Grand Paris by the European Commission as part of the CIRC BOOST project has enabled the hiring of a person fully dedicated to managing the project during 3 years. On the other hand, the deployment and development of the digital tool via the 18-month contract with SKOP is self-financed by the MGP. To ensure the platform's long-term viability, it is therefore necessary to find additional sources of funding to enable the definitive tool to be maintained. The Metropole therefore needs to find a sustainable economic model to ensure the tool's long-term viability in its definitive version - consideration is currently being given to various scenarios and their financial impact and additional sources of fundings by public actors, as Region Ile-de-France, as well as private actors as eco-organisms (Valobat, EcoMinero, etc.) are examined. The support of WP6 in defining the business model of the platform is also considered as a lever in this search for sustainability.

				2nd part: Annex 1 translated in English and available
1 3	The Year 1 report of the Pilot 3 is mostly clear and adequately detailed. The objective of Pilot 3 (page 34) is to demonstrate the possible application of climate-neutral structural solutions and materials. **Please consider using another term instead of climate-neutral** (such as low-carbon) because - obviously - the target is not to develop solutions for net zero greenhouse gas emissions.	3	3.3.1.1	The term '**climate-neutral'** is replaced with **low-carbon and resource efficient solutions**.
1 4	**Please add in the beginning of the Pilot 3 report a short statement of the current status of the Pilot 3**. This would improve the easy readability of the report. For instance: The current status of the work (in the end of year 1) is that following essential tasks are ready: architectural and conceptual structural design, detailed structural design; database of potential sources of recycled and reusable materials, procurement of equipment and materials, numerical prototype and testing.	3	3.3.1	This text is added at the beginning of section 3.3.1: At the end of year one, the following essential tasks have been completed: architectural and conceptual structural design, detailed structural design, creation of a database of potential sources for recycled and reusable materials, procurement of equipment and materials, as well as numerical prototyping and testing.
1 5	As the objective of Pilot 3 is "to increase deployment and market uptake of innovative climate-neutral circular solutions for the Serbian construction industry", the **progress reports should also discuss the success and relation of the work regarding climate-neutrality (or low-carbon building).**	3	3.3.1. 1	This text is added at the end of current section 3.3.1.1: The objective of Pilot 3 is to enhance the deployment and market adoption of innovative low-carbon and resource-efficient circular solutions in the Serbian construction industry, with a particular focus on activities supporting this goal. In the first year, a one-day seminar titled A Step Toward a Carbon-Neutral and Circular Construction Industry was organized for key target groups, including researchers in sustainable construction, construction waste treatment companies, precast concrete companies, steel companies, architectural and design bureaus, and investors. The

				event was attended by 60 participants in person and 12 online. The structural design of house elements was carried out in collaboration with industry partners to develop low-carbon and resource-efficient solutions suitable for industrial application. These include reusable and modular structural elements, concrete with 100% coarse recycled aggregate, high-volume fly ash concrete, reused steel, reused brick for infill walls, and recycled rubber for seismic isolation. A comprehensive sustainability evaluation of these solutions will be conducted for a pilot house as a whole, in collaboration with WP5. This process has already begun with the preparation of local inventory data required for life cycle assessment analysis.
16	The Year 1 report of the Pilot 4 is also mostly very clear and adequately detailed. Regarding Pilot 4, to clarify the current status of RCA and the potential for using RCA in concrete, **please explain the related building regulations in Norway in the beginning of the report** (as a reference, in Finland according to the new Government Decree concrete aggregates will no longer be classified as waste (Government Decree on the criteria for the end of the classification of concrete aggregates as waste 466/2022). The new decree allows the use of concrete aggregates as a raw material for ready-mixed concrete and concrete products, as well as in civil engineering, building and landscaping, under certain conditions. This also means that crushed concrete aggregate is CE-marked.). Although there is information on page 82, it is important to provide prompt information on the	4	3.4.1.1	In Norway, there is Kontrollrådet, the Norwegian Control Council, which administers certifications within the building materials sector and, in the case of RCA production, approves the system for the production of RCA. After production, certification for RCA is mainly described in 3 documents that refer to the use of RCA in concrete production. Two of them are EU standards Concrete NS-EN 206:2013+A2+NA Specification, performance, production and conformity Betong Spesifikasjon, egenskaper, framstilling og samsvar and NS-EN 12620:2002+A1+NA Tilslag for betong Aggregates for concrete, both

	current legal status of RCA, RAC and the novelty of the case in the beginning of the report, would be useful.			extended by Norwegian annex where the RCA requirements (max or mix allowed value for certain properties, need for declaration of properties), classification (two groups NA and NB), and quantities allowed in concrete (for fraction 0-4 mm and ≥ 4 mm and in NA and NB quality). The third document that is very often used by the industry is Norsk Betongforening, NB Publikasjoner no. 18 Tilslagsmaterialer for betongformål (1988), which is presently under revision. Iveta Novakova from UiT provided robust data about RCA, and also participated in revisions of the new version.
17	**Please check and clarify or correct the correspondence of the text** "Figure 3.4-5 shows maximum amount for replacement of the natural aggregate by RCA according to the Norwegian Standard" with the Figure 3.4-5 (Preliminary architectural design of the new Gaia Vesteralen museum made by LUA).	4	T3.2	Additional text was added to section T3.2 and the content of table 3.4-3 was updated. Text: Besides the limits given in Table 3.4-3, the replacement ratio can be higher under the condition that the use of concrete with RCA is taken into account during the planning phase and additional tests are performed to certify the concrete's performance.
18	**Please, clarify if any tests regarding the properties RAC (early and or hardened) have started.** As said in the report (regarding Pilot 4), mix design for individual concrete types and levels of RCA replacement depends on the strength class and exposure class of the concrete, and concrete with higher replacement ratios than stated in the national annex of EN 206 has to be tested and considered during the design stage.	4	T3.3	So far, there were two small batches of test RAC prepared with RCA produced from coredrills. Nevertheless, the quantity of RCA was so small that regular and reasonable testing of concrete properties was not possible. Therefore, optimization and testing of concrete with RCA will fully stat after the Demolition and production of RCA scheduled for 04-09. 2025.

19	**Please also clarify (for example with a table) what are the types of structures and their performance requirements** (in terms of strength, exposure class, workability class if relevant) which will be manufactured of RAC.	4	T3.3	A table is added to clarify concrete types used for structure and their requested properties.
20	**The information about the KPIs is (page Pilot 4) not quite clear.** In the beginning of the report, it is said that the first year of pilot 4 was mainly focused on planning and obtaining permits for all activities. In addition, the pilot is delayed. On the other hand, on page 86 it is said that three out of five KPIs for Pilot 4 have already been achieved such as there have been more than 20 construction companies and other industry stakeholders that visited or participated in conducted pilot phases so far. As the Pilot is only in its early stages, the efforts for involving stakeholders should not end, even if several construction companies have already somehow participated in these phases.	4	3.4.3	Added explanation. We will continue to approach local businesses and involve them in all 3 parts of pilot 4. Text: As the pilot 4 consist of 3 activities there were companies and stakeholders involved in the demolition – open tender and construction – structure design and desig of experst for example for ventilationa nad fire safety. We still need to reach out to more stakeholders and we will continue to work towards local businesses.
21	The Year 1 report of the Pilot 5 well presents information about the work done and achievements within the Pilot. For example the Table 3.2-5 (The type of developed mixture, their used volumes on site and recycled aggregate portion) represents a good way of reporting essential results by describing the shares of RCA used in concrete in terms of defined environmental exposure class, strength and workability. In addition, Table 3.2-6 well presents the possibilities to reduce the carbon footprint of concrete with the help of different blended cements. However, either of these addresses the challenges and problems, or on the other hand specific novel achievements of the projects nor provide analyses to be considered in the next phases of the project. According to Table 3.2-5, the percentage of RCA varied between 50-71 %. However, the target of the Pilot 5 written in the GA is to "expand the adoption of concrete made with 100% of recycled aggregates, to wide	5	3.5.2 (T3.3.2)	The original goal of achieving 100% recycled aggregate (RA) use in structural concrete was intended as "up to 100%", reflecting technical feasibility rather than a fixed target. Initial tests using single-fraction RA showed promising results, but maintaining such quality in standard industrial recycling proved unrealistic. As a result, RA content dropped to as low as 25% at the beginning of the project. To address this, we developed new concrete mix designs using 2–3 RA fractions and blended cements (e.g., CEM II/A-M, CEM V), along with improved RA processing methods (e.g., washing). These adjustments have enabled us to increase RA content up to 75–100% in selected applications, depending on

	industrial implementation across large-scale residential projects. This includes: (i) subbase concrete layer; (ii) reinforced concrete walls (iii) reinforced concrete columns; (iv) concrete floors (ground- and column-supported), retaining walls, (v) wall tiles; (vi) urban furniture and (vii) facade panels. " **Please add a discussion to explain the relation of the achieved results with the original objective. Please note the <u>JRC Science for policy report (2023)</u>** <u>Use of recycled aggregates in concrete. Opportunities for upscaling in Europe.</u> [1]			structural and exposure class requirements. Application decisions are made in close collaboration with designers and structural engineers to ensure durability is not compromised. For example, RA concrete is now used for selected structural walls, and pilot production of facade panels with RA is underway. Although full 100% RA use across all elements remains challenging, our ongoing on-site development is steadily increasing RA utilization. Notably, Rebetong production at the MOCU site is already above the European average (JRC 2023).
22	As already commented regarding D3.1, **the meaning of the KPIs (presented in Table 3.5-5 -List of set key-performance indicators (KPI) within the pilot 5 and their current status) is partly unclear** because the point of comparison is not explained.	5	3.5.3	The list of KPIs was supplemented with explanation how are those percentages and ratios calculated.

* Pilot number

** Section designation (e.g. 2.3.1) in which the certain comment is addressed

***Short answer on comment or suggestion

PILOT 1 : Comments 3-4

PILOT 2 : Comments 5-12

PILOT 3 : Comments 13-15

PILOT 4 : Comments 16-20

PILOT 5 : Comments 21-22

1 Introduction

The Pilot Year 1 Report outlines the activities carried out under WP3 during the first year of pilot deployment, spanning from November 2023 to November 2024, approximately 18 months after the project launch in June 2023. The report aims to offer a comprehensive yet concise overview, evaluating results, progress, and trajectory. It also identifies challenges, opportunities, lessons learned, and best practices, while reflecting on adjustments to be implemented in the following year.

A similar report will be prepared at the end of Year 2 (month 30) to summarize WP3 activities in the subsequent period.

These reports complement the technical reports by offering a different perspective. While the technical report takes a top-down approach to assess the work package, this document adopts a bottom-up perspective, focusing on detailed insights at the individual pilot project level. It not only documents progress but also reflects on it, using the pilot operational plans defined in **Deliverable 3.1 – Pilot Deployment Strategy (PDS)** as a reference.

The remainder of this chapter provides a narrative summary of efforts during Year 1. Chapter 2 details WP3 activities, including baseline completion and training and dissemination efforts for each use case. Chapter 3 reviews implementation activities and evaluates progress, while Chapter 4 presents the conclusions.

The GANTT chart for CircBoost WP3 with the focus on the first year of pilots implementation is shown in the figure below. For the first 18 month of project duration, both milestones (M1 and M2) have been reached since PDS and Pilot year 1 Report have been delivered, this proving that pilots implementation is aligned with plans.

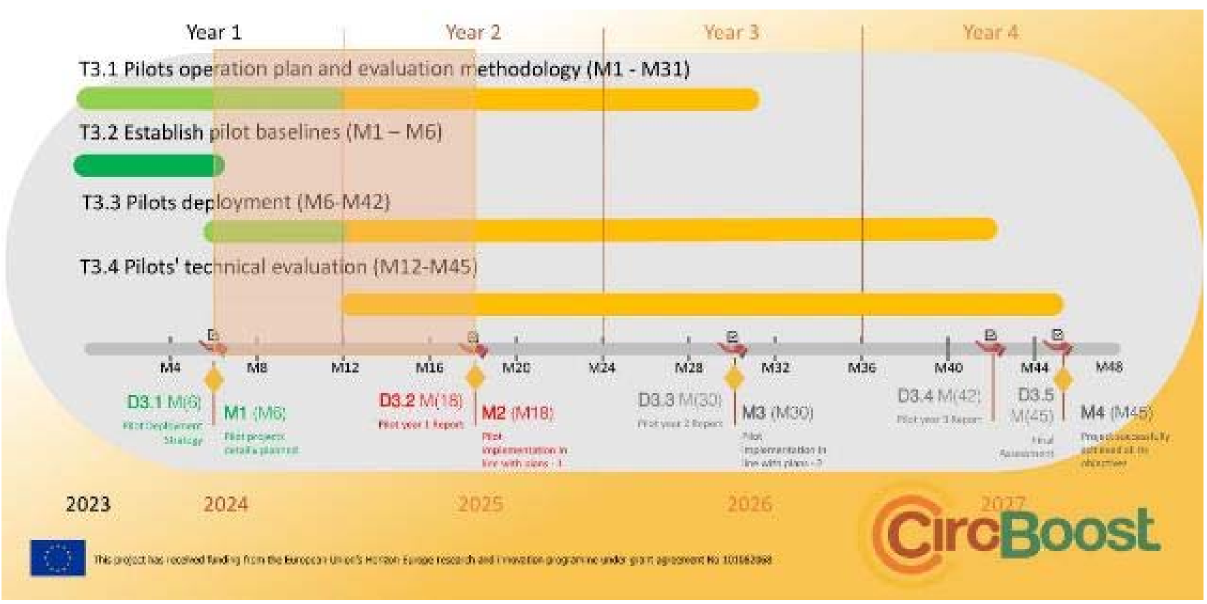


Figure 2.1-1 – Gantt chart for WP3 - Pilots

The requirements for WP3 in the first year concerned mainly the prepartion work and planning in the fields of the pilots. In this regard, preliminary sampling, development of protocols, equipment procurement (Pilot 1), development of digital platform (Pilot 2), structural design, reused or recycled materials procurement, numerical prototype testing (Pilot 3), pre-demolition audit, construction permits obtained (Pilot 4), design, testing and application of innovative concrete material (Pilot 5) were the main tasks dealt with.

The tracking of progress/impact also continued this year with use of milestones and key performance indicators defined the PDS. In addition, comparison with already established baselines together with pilot evaluation methodology will provide reliable monitoring and evaluation during the second year of pilots campaign.

2 Activities of the CircBoost Pilot projects

2.1 Pilots deployment strategy

The Pilot Deployment Strategy (PDS) is a document outlining specific activities across a timeline for the deployment of the five pilots within the CircBoost project. It's been developed during the first 6 months of project life and delivered at the end of month 6.

This document provides a comprehensive overview of activities related to pilot projects, detailing implementation methods and evaluation procedures. It facilitates the alignment of efforts across work packages and supports meticulous planning. Crucially, it **initiates feedback loops between the pilots and other work packages**, ensuring the provision of specific data and materials necessary for their activities. These horizontal activities between WP3 and other WPs are briefly presented in the chapter 2.2 while in details will be given as a part of Technical report, i.e. outcomes of these WPs.

For other stakeholders, such as participants in related "sister" projects or potential business users—the ultimate target audience of this initiative—the PDS document offers a clear **understanding of the pilots' objectives and the innovative technical solutions being developed**. There was a planty of interactions with "sister" projects during the first year, organized in the form of **seminar** followed by **webinar** as starting points for mutual understanding of projects and pilots/use cases within them. In September 2024 all three "sister" projects (CircBoost, RECONSTRUCT and Woodcircles) participated in the **panel discussions** organized under the umbrella of World Green Building Week 2024 National Conference, Belgrade, Serbia.

The PDS also serves as a **critical tool for project management**, offering a detailed timeline of all pilot activities. This facilitates progress tracking, identification of challenges, and timely implementation of measures to mitigate risks. The proposed changes in timeline, re-order or addition of subactivities also refers to the list of activities and timeline defined in PDS.

Finally, PDS enables an **overall assessment of the project's success** by comparing achieved Key Performance Indicators (KPIs) with planned targets for each innovative solution but also a **periodical assessment of particular pilot** by comparing achieved technical KPIs with targeted values given in PDS. Prior to targeting, the baselines were established through the current state of the art (SOA) in specific fields and specially focused on the local/regional level where innovative technical solutions will be developed. This ensures accountability and highlights the project's contributions to its broader objectives.

2.2 Horizontal activities within the project

During the period M6–M18, WP3 had significant interaction with other Circ-Boost WPs.

Interaction with WP2 consisted of:

- Mapping of stakeholders for each pilot, including pilot participants, pilot owners and developers, local and global third-party stakeholders;
- Presentation of Pilot 1 and Pilot 3 at the Sister Project World Green Building Week event in September 2024 in Belgrade.

Interaction with WP5 consisted of:

- Definition of goal and scope for the LCA comparative analysis to be performed on the DfD/R prototype being developed within Pilot 1
- Definition of inventory data needed for LCA of 3R house in Pilot 3

Interaction with WP6 consisted of:

- Definition of inputs for the Value Chain Analysis to be performed on pilots.

Interaction with WP7 consisted of:

- Development of a Pilot 1 construction site visit guide and on-site training material;
- Execution of first training related to soil decontamination activities within Pilot 1.
- Execution of first training related to LCA analysis and EPD declaration within Pilot 3

Interaction with WP8 consisted of:

- Presentation of Pilot 1 within the featured technical article on the EU BUILD UP portal[1]
- Promotion of pilots activities through the partners websites, at the conferences, exhibitions and publications

The detailed justification of activities will be given for each WP in Technical report.

[1] https://build-up.ec.europa.eu/en/resources-and-tools/articles/circ-boost-new-action-circular-construction-europe

3 Implementation/Execution of the pilots

3.1 Implementation of the Pilot 1 – Barcelona

3.1.1 Summary

3.1.1.1 Objectives

The overall objective of the pilot is to achieve full traceability and valorization of >90% of the recovered material in a demolition project in Barcelona, through the development and deployment of novel BIM-based selective demolition and decontamination techniques, as well as to achieve the use of the recovered material in new high-added value applications with a Sustainability Index (SI) -economic, environmental and social- of these products, at least 40% higher than offered by current best practices.

The overall objective is to be achieved by pursuing specific aims within different stages of the project's life cycle:

- **Demolition stage:** use of BIM-based digital twins for the generation of material and element databanks, in particular, during excavation. Nature-based solutions for soil decontamination and reuse.
- **Design stage:** integration of BIM models with LCA and multi-criteria decision-making tools to enable sustainability-based assessment of DfD/R structures.
- **Construction stage:** construction and validation of a DfD/R modular concrete panel prototype building and use of low-cost wireless sensors and NFC tags for traceability.

The LaMercedes project is being developed by ConrenTramway, with Batlleiroig architects and Elisava School of Architecture. Within the project itself, the Circ-Boost contribution is twofold. On the site itself, the full soil decontamination activities will be taken on by the Circ-Boost consortium to implement novel remediation techniques that will allow the reuse of soil on-site. Off-site, modular elements designed for deconstruction and reuse will be developed and validated through a prototype structure, as a demonstration of what can be implemented in the LaMercedes project at a later stage, since the duration of activities on site will exceed the duration of the Circ-Boost project. Both aspects (on- and off-site) will be accompanied by different digital solutions.

3.1.1.2 General information about work done in the 1st year

The first year of Pilot 1 execution saw advances towards all the Pilot objectives and in line with scheduling.

Within the soil decontamination line, preliminary sampling and deployment of nature-based solutions for decontamination yielded positive results, allowing moving into the preparation stage for full-scale deployment on the Pilot site. Additionally, protocols are under development for cloud point scanning of excavation, ensuring BIM-compatibility and traceability of the excavation material.

Within the Design for Deconstruction and Reuse (DfD/R) prototyping activities, a schematic design of the prototype to be constructed and validated at the ACCIONA DemoPark was completed and the detailed design is being finalized with logistical activities commencing.

Finally, within the low-cost wireless sensors line, equipment procurement has been completed, as well as a traceability protocol and software, with laboratory validations commencing.

Due to the site still being inoperable (awaiting construction permits), no more on-site work could be done.

3.1.2 Main activities and results

T3.1 Pilot operation plan and evaluation methodology (UPC, ACCIONA, Control Demeter, TESIS, Smart Engineering)

The Pilot 1 Task 3.1 (T3.1) consists of equipment acquisition and deployment, scheduling, evaluation methodology, deployment plan and reporting.

By the end of month 18, most of the activities have concluded with two ongoing, pilot deployment plan (for considering any deviations that may occur) and reporting (interaction with WP3, 5, 6, 7 and 8).

T3.2 Establishing pilot baselines (UPC, ACCIONA, Control Demeter, TESIS, Smart Engineering)

This task, consisting of the state-of-the-art for each solution and establishment of baselines with comparisons, was concluded at the end of month 6.

T3.3.1 and T3.3.2 Preliminary surveying and soil decontamination (Control Demeter, UPC)

The soil decontamination activities had, as a starting point, an initial screening performed by Control Demeter (as a partner) and Eurecat (as a subcontracted party) before the beginning of the Circ-Boost project in which soil particle size distributions were determined for four sites, as well as the main contaminants, Figure 3.1-1. The results indicated contamination by metals on site M1 (Sb, As, Pb, Cu, Mb), hydrocarbons on site M2 (PAH, TPH) and a mixed contamination on site M3.

Figure 3.1-1 - Pilot 1 site for preliminary screening prior to the Circ-Boost project (left) and particle size distributions (right)

Based on these results, it was determined to select five sites for proof of concept testing of the novel, nature-based solutions (NBS) for soil decontamination. The sites (Q11-1, Q11.5, Q3.4, Q3.8 and Q3.10, Figure 3.1-2) were selected so that a single contaminant type is predominant in each of them (hydrocarbons, PAH, TPH, PCE, metals).

Figure 3.1-2- Pilot 1 sites for proof-of-concept testing of NBS for soil decontamination

The first step was the excavation at the sites, followed by sampling for testing prior to treatment, **Figure 3.1-3**

Figure 3.1-3 - Excavation and stockpiling before sieving

The second step was sieving the material from the five sites through 4 and 20 mm sieves, Figure 3.1-4. After sieving, samples were also taken from each fraction from each site for characterization and contamination testing.

Figure 3.1-4 - Sieving of the material from the five sample sites

The following nomenclature was adopted for each site: „.0“ designates the unsieved material, „.1/2“ designates the sieved material above 20 mm, „.3“ designates the material between 4 and 20 mm and „.4“ designates the material below 4 mm. For example, Q11.1.0 refers to the unsieved material from site Q11.1, whereas Q3.10.4 refers to the sieved material smaller than 4 mm from site Q3.10.

Finally, the NBS treatment (Figure 3.1-5) was applied to all „.4“ samples as it was expected that sieve cut-off at 4 mm woud lead to the more coarse material already containing sufficiently less contamination to be qualified as soil usable for different construction purposes like backfilling.

Figure 3.1-5 - NBS treatment application

The results of the characterization before NBS treatment are shown in Figure 3.1-6. The values marked in red designate soils unfit for any use (landfilling at special designated sites), whereas the values in yellow can be used for „industrial“ purposes. The first column represents the „.0“ samples, i.e. before sieving and the subsequent three columns are „.1/2“, „.3“ and „.4“ samples, respectively. It can be noticed that the red values observed in the „.0“ column generally disappear or convert to yellow in the „.1/2“ and „.3“ samples, confirming that sieving at a cut-off of 4 mm leads to the contaminants remaining predominantly in the finest fraciton „.4“ for which exceeded values can be observed (and are generally exceeded relatively more than for the „.0“ sample as they constitute a smaller portion of the overall material, typically around 1/3).

RD 9/2005 / EVALUACIÓN, Impacto por actividades humanas / DETALLES DE LAS MUESTRAS	Otros usos No impacto	NGR Urbano ligero	NGR Indust apreciable	RESULTADOS INICIALES - PILAS 0						RESULTADOS PILAS 1-2 (Gravas)						RESULTADOS PILAS 3 - Fracción fina					RESULTADOS PILAS 4 - ULTRAFINO					
Tipo de muestra				Q11.1.0-A	Q11.1.0-B	Q11.5.0	Q3.4.0	Q3.8.0	Q3.10.0	Q11.1.1/2A	Q11.1.1/2-B	Q11.5.1/2	Q3.4.1/2	Q3.8.1/2	Q3.10.1/2	Q11.1.3-A	Q11.1.3-B	Q11.5.3	Q3.4.3	Q3.10.3	Q11.1.4-A	Q11.1.4-B	Q511.5.4	Q3.4.4	Q3.8.4	Q3.10.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 3.1-6 - Soil characterization before and after sieving (but before NBS treatment)

As explained, the NBS treatment was applied to the ".4" specimens with results shown in Figure 3.1-7. As can be seen from the results, comparing the second and third columns (the ".4" samples before and after the NBS treatment), most of the exceeded values were successfully lowered either completely or to an "industrial use"-designated soil, with the only exception of several metals such as arsenic, lead and zinc whose concentration was, nonetheless, reduced.

RD 9/2005		Otros usos No impacto	NGR Urbano ligero	NGR Indust apreciable	RESULTADIOS INICIALES - PILAS 0						RESULTADOS PILAS 4 - ULTRAFINO						REMEDIACIÓN SUELOS NBS					
EVALUACIÓN, Impacto por actividades humanas																						
DETALLES DE LAS MUESTRAS:																						
Tipo de muestra					Q11.1.0-A	Q11.1.0-B	Q11.5.0	Q3.4.0	Q3.8.0	Q3.10.0	Q11.1.4-A	Q11.1.4-B	Q511.5.4	Q3.4.4	Q3.8.4	Q3.10.4	Q11.1.4-A	Q11.1.4-B	Q511.5.4	Q3.4.4	Q3.8.4	Q3.10.4
RESULTADOS																						
materia seca	% peso				84,4	84	85.1	80.8	91.2	90.3	82.3	82.7	85.1	85.5	91.8	90.3	82.3	82.7	85.1	85.5	91.8	90.3
TAMAÑO PARTÍCULA																						
fracción ,2mm (prep, secada a 40ºC)	%				76	86	71	72	75	73	87	86	78	83	86	85						
fracción >2mm (prep, secada a 40 °C)	%				24	14	29	28	25	27	13	14	22	17	14	15						
METALES																						
antimonio	mg/kgms	6	6	30	4,4	2.9	5	22	7.5	5.1	2.4	2.9	24	2.5	18	5.8	2.9	2.8	6.7	3.3	8.2	5.4
arsénico	mg/kgms	30	30	30	24	21	30	45	49	22	18	20	39	23	52	23	24	20	34	24	48	23
bario	mg/kgms	500	880	1000	390	400	470	430	600	150	320	380	390	220	150	88	380	440	1.8	300	790	280
cadmio	mg/kgms	2.5	5.5	55	0,85	1.3	1.6	0.73	9.1	0.71	0.87	1.1	1.6	0.77	17	1	0.84	58	44	37	37	56
Cromo (VI)	mg/kgms	1	10	25	<0,4	<0,4	0.72	<0,4	<0,4	0.95	<0,4	<0,4	0.81	<0,4	<0,4	1.24	<0,4	<0,4	0.94	<0,4	<0,4	1.34
cobalto	mg/kgms	25	45	90	9,4	9.6	13	12	29	10	9.6	11	13	8.7	9.5	11	9.4	11	12	10	10	11
cobre	mg/kgms	90	310	1000	340	88	150	4400	150	170	88	120	240	78	170	150	96	91	150	120	150	150
mercurio	mg/kgms	2	3	30	0,70	0.86	0.84	0.3	1.6	0.61	1.1	0.8	1.3	0.32	4.6	1.6	0.83	0.76	1.4	0.45	2.6	0.86
plomo	mg/kgms	60	60	550	160	190	290	400	520	190	200	180	790	150	730	170	240	170	400	210	790	150
molibdeno	mg/kgms	3.5	7	70	7,0	1.8	7.4	4.6	12	4.1	3	2.2	4.7	5.1	12	5.2	3.2	1.8	3.5	3.3	7.7	4.6
niquel	mg/kgms	45	470	1000	49	23	29	39	28	26	60	25	35	23	23	28	26	24	29	24	26	28
selenio	mg/kgms	0.7	7	70	0,95	1.1	1.2	1.5	1	0.62	0.87	0.97	1.4	1.1	0.97	0.65	0.79	0.88	1.2	1.1	0.76	0.75
talio	mg/kgms	1.5	4.5	45	<0,4	<0,4	0.78	<0,4	0.63	<0,4	<0,4	<0,4	1.4	<0,4	0.44	<0,4	<0,4	<0,4	1.5	<0,4	0.4	<0,4
estaño	mg/kgms	50	1000	1000	140	14	19	350	25	28	14	13	82	7.5	67	16	13	12	18	8.4	31	14
vanadio	mg/kgms	135	190	1000	35	37	48	43	45	38	32	36	44	38	41	39	42	41	46	42	41	43
zinc	mg/kgms	170	650	1000	280	220	490	740	2200	280	270	220	1500	370	3200	420	260	220	590	410	2000	330
COMPUESTOS AROMÁTICOS VOLÁTILES																						
FENOLES																						
HIDROCARBUROS AROMÁTICOS POLICÍCLICOS																						
naftaleno	mg/kgms	1	8	10	1,5	0.82	<0,02	0.1	0.09	<0,02	0.38	0.16	<0,02	<0,02	0.07	<0,02	0.08	0.07	<0,02	<0,02	0.22	<0,02
fluoranteno	mg/kgms	8	80	100	0,47	0.7	0.23	6.5	2.5	0.28	0.91	0.22	0.55	0.99	5.1	0.47	0.23	0.18	0.26	0.7	2.4	0.52
pireno	mg/kgms	6	60	100	1,1	0.79	0.2	5.4	1.8	0.23	1.8	0.43	0.45	0.81	3.9	0.39	0.63	0.27	0.24	0.59	1.8	0.42
benzo(a)antraceno	mg/kgms	0.2	2	20	0,19	0.39	0.14	2.6	1.3	0.16	0.55	0.16	0.32	0.53	2.3	0.27	0.13	0.11	0.15	0.32	1.1	0.26
benzo(b)fluoranteno	mg/kgms	0.2	2	20	0,20	0.35	0.14	2	1.1	0.16	0.38	0.16	0.28	0.41	1.7	0.27	0.18	0.15	0.16	0.29	0.88	0.27
benzo(a)pireno	mg/kgms	0.02	0.2	2	0,21	0.39	0.14	2.3	1.2	0.18	0.45	0.17	0.33	0.46	1.9	0.3	0.22	0.16	0.18	0.34	0.96	0.29
dibenzo(a,h) antraceno	mg/kgms	0.03	0.3	3	0,04	0.06	0.02	0.32	0.21	0.03	0.07	0.03	0.05	0.05	0.28	0.04	0.08	0.03	0.03	0.06	0.05	0.05
indeno(1,2,3-cd)pireno	mg/kgms	0.3	3	30	0,16	0.31	0.09	1.4	0.7	0.12	0.27	0.12	0.24	0.26	1.2	0.18	0.17	0.12	0.13	0.21	0.55	0.21
COMPUESTOS ORGANOHALOGENADOS VOLÁTILES																						
tetracloroeteno	mg/kgms	0.1	1	10	<0,02	<0,02	0.08	0.17	<0,02	<0,02	0.02	0.06	0.12	0.21	<0,02	<0,02						
CLOROBENCENOS																						
CLOROFENOLES																						
POLICLOROBIFENILOS (PCB)																						
PCB Totales (7)	µg/kgms	10	80	800	570	24	26	<7,0	<7,0	110	360	33	33	<7,0 #	<7,0 #	<7,0 #	240	22	12	<7,0 #	<7,0 #	<7,0 # *
PESTICIDAS CLORADOS																						
p,p-DDT	µg/kgms	200	2000	20000	<6,5	<6,6	39	470	82	420000	<6,0 #	<16 #	2300	5700	350	880000						
p,p-DDD	µg/kgms	700	7000	70000	<6,5	<6,6	3	28	7.2	21000	<6,0 #	<16 #	270	610	20	76000						
p,p-DDE	µg/kgms	600	6000	60000	<6,5	31	94	30	41	2000	<6,0 #	34	870	140	63	14000						
HIDROCARBUROS																						
suma alif/arom C5-C35	mg/kgms		50		16000	7000	120	290	160	390	12000	7300	180	140	190	870	6400	4000*	110 *	160	120	500 *
acetona	mg/kgms	1	10	100	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Figure 3.1-7 - Results of NBS treatments

The results present a confirmation of the adopted approach which will be upscaled in the following period to the entire Pilot 1 site.

T3.3.3 Development of BIM models from cloud point scanning of excavation (Control Demeter, UPC)

During these activities, point cloud scanning of the excavated material was carried out, Figure 3.1-8. The generated point clouds were successfully converted to BIM objects that could be manipulated, allowing for attribute assignment and property determination, such as volume, Figure 3.1-9.

Figure 3.1-8 - Point cloud scanning of the excavated material

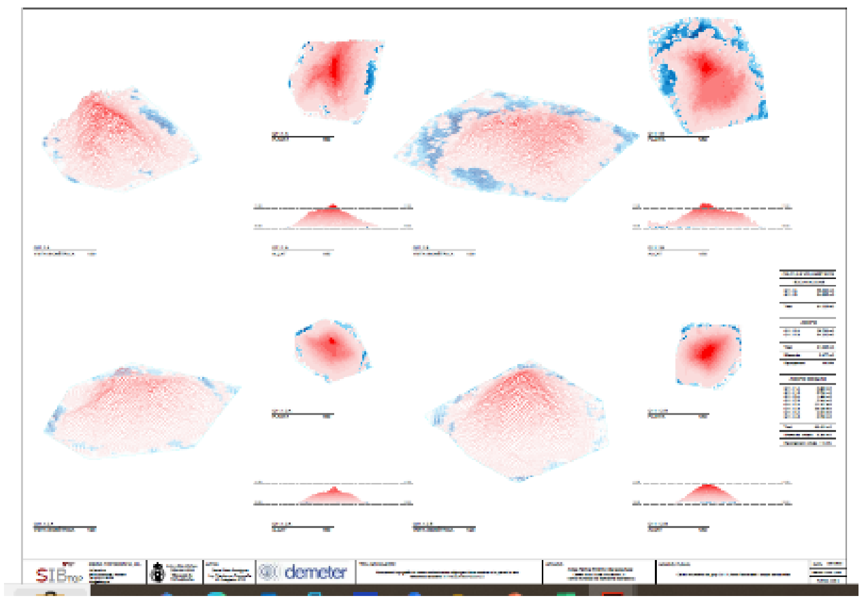


Figure 3.1-9 - Importing of point clouds into BIM.

T3.3.4 RFID sensors for traceability (Smart Engineering, UPC)

The third line of action within Pilot 1 is the development and deployment of Radio Frequency Identification (RFID) tags for the multiple life cycle traceability of construction elements such as the DfD/R panels to be used in the prototype structure.

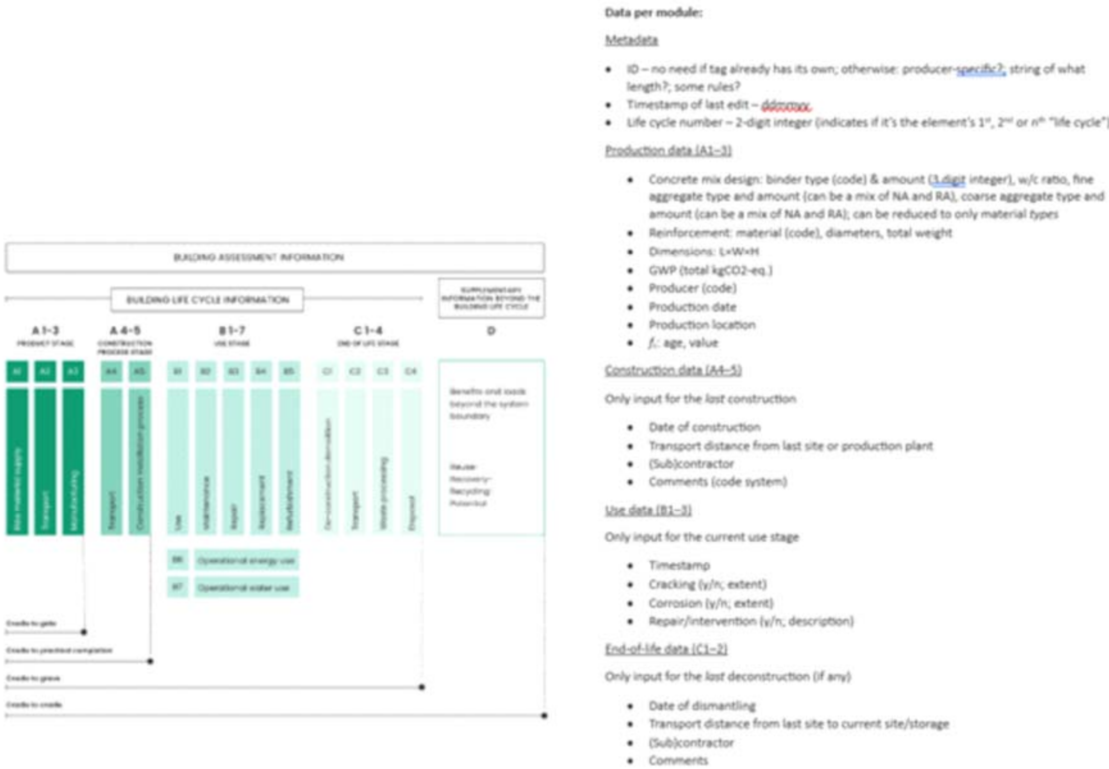
After evaluating the state of the art on the technology and application of different traceability methods in construction (QR codes, NFC, RFID tags), the choice was made to use UHF RFID 8Kb user Memory tags a Monza X-8K Dura chip and an 8Kb user memory together with a reader device, Figure 3.1-10

The next step was the definition of a protocol for recording and storing information about the element/panel related to all life cycle stages and multiple life cycles, Figure 3.1-11.

This protocol was programmed into an Android app running on the reader opeating system allowing input of the required information, Figure 3.1-12.

Finally, the RFID functioning embedded in concrete is under validation via laboratory testing at UPC.

Figure 3.1-10 - RFID sensors selected for application (left) and reader (right)



Data per module:

Metadata

- ID – no need if tag already has its own; otherwise: producer-specific?, string of what length?; some rules?
- Timestamp of last edit – ddmmyy
- Life cycle number – 2-digit integer (indicates if it's the element's 1st, 2nd or nth "life cycle")

Production data (A1–3)

- Concrete mix design: binder type (code) & amount (3 digit integer), w/c ratio, fine aggregate type and amount (can be a mix of NA and RA), coarse aggregate type and amount (can be a mix of NA and RA); can be reduced to only material *types*
- Reinforcement: material (code), diameters, total weight
- Dimensions: L×W×H
- GWP (total kgCO2-eq.)
- Producer (code)
- Production date
- Production location
- *f*c: age, value

Construction data (A4–5)

Only input for the *last* construction

- Date of construction
- Transport distance from last site or production plant
- (Sub)contractor
- Comments (code system)

Use data (B1–3)

Only input for the current use stage

- Timestamp
- Cracking (y/n; extent)
- Corrosion (y/n; extent)
- Repair/intervention (y/n; description)

End-of-life data (C1–2)

Only input for the *last* deconstruction (if any)

- Date of dismantling
- Transport distance from last site to current site/storage
- (Sub)contractor
- Comments

Figure 3.1-11 - Protocol for information storage

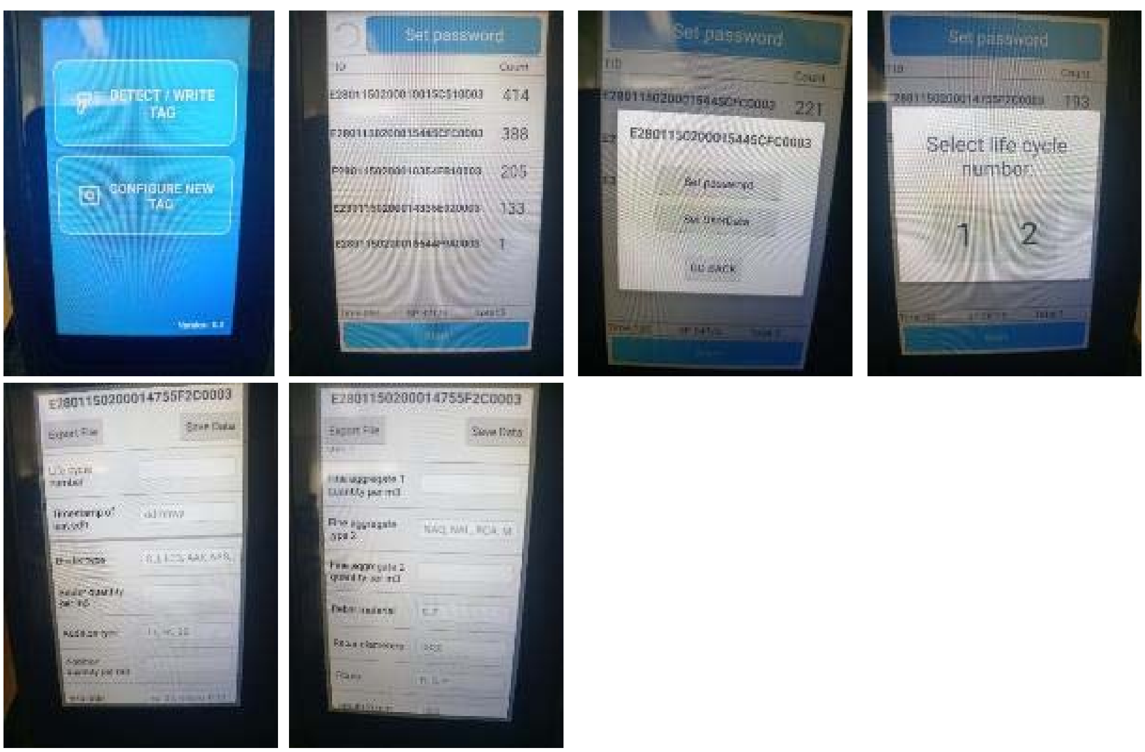


Figure 3.1-12 - Android app developed for the RFID reader

T3.3.5 and T3.3.6 DfD/R prototyping (UPC, TESIS, ACCIONA)

The objective of this line within Pilot 1 is the development of a modular DfD/R precast concrete panel system, the execution of a pilot structure, its testing under loads, dismantling and second construction.

Since the LaMercedes project itself will last well beyond the Circ-Boost project, the prototype is developed as a demonstrator for potential later use on the site itself (pending approval by the developer, ConrenTramway).

The first year of activities consisted of the schematic and detailed design of the solution.

The starting point was a one-way slab modular precast concrete panel system previously developed by TESIS, Figure 3.1-13. Therefore, the first step in the prototype development was the modification of the system to enable two-way elements (slabs and walls) to be constructed. Furthermore, the original prestressing technology of using shape-memory alloys was substituted with high-strength steel bar (Dywidag or similar) for prestressing.

Figure 3.1-13 - DfD/R precast concrete panel system previously developed by TESIS

The prototype structure is to be constructed at the ACCIONA DemoPark in Madrid. Hence, the first input needed were the dimensions of the available foundations, Figure 3.1-14. The choice was made to base the solution on the 5.8×5.2×0.9 m foundation.

Existing foundations in ACCIONA Demopark

	Dimensions	Nr units
	4.30m x 3.15m x 0.20m	2
	5,80 m x 5, 20m x 0.90m* (*0.50m built below ground level + 0.40m built above ground level)	2

Figure 3.1-14 - Available foundations at the ACCIONA DemoPark

The module was redesigned in 1200×600×200 mm dimensions to allow for two-directional prestressing, Figure 3.1-15 with lifting eyes for preassembly and lifting. The module will also be lightened by including expanded polystyrene blocks within the modules. Considering their dimensions, a single-story building was designed as a prototype, Figure 3.1-16. The presence of doors and windows was also considered for representativeness. The only in-situ element considered are the perimeter foundation beams on which the walls will be placed. The other non-modular elements will be the four corner columns and perimeter beam for the slab.

Finally, a full construction procedure (construction stages) wes designed, Figure 3.1-17, as well as design checks for gravity and potential horizontal loads and determining the required level of prestress, Figure 3.3-18.

The remaining steps are the final detailed design within which the geometry and final design of the structure might be altered depending on on-site conditions and production capacities (e.g. reduction from 3 to 2 rows of elements per height and elimination of shear keys in the modules).

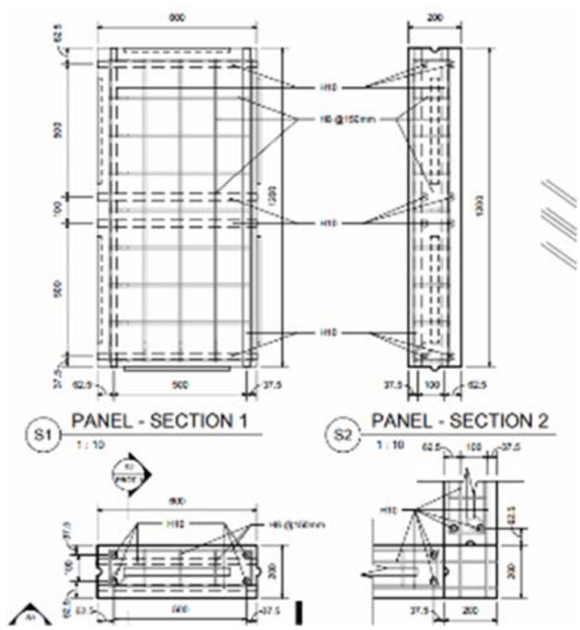


Figure 3.1-15 - Precast concrete module for the DfD/R prototype

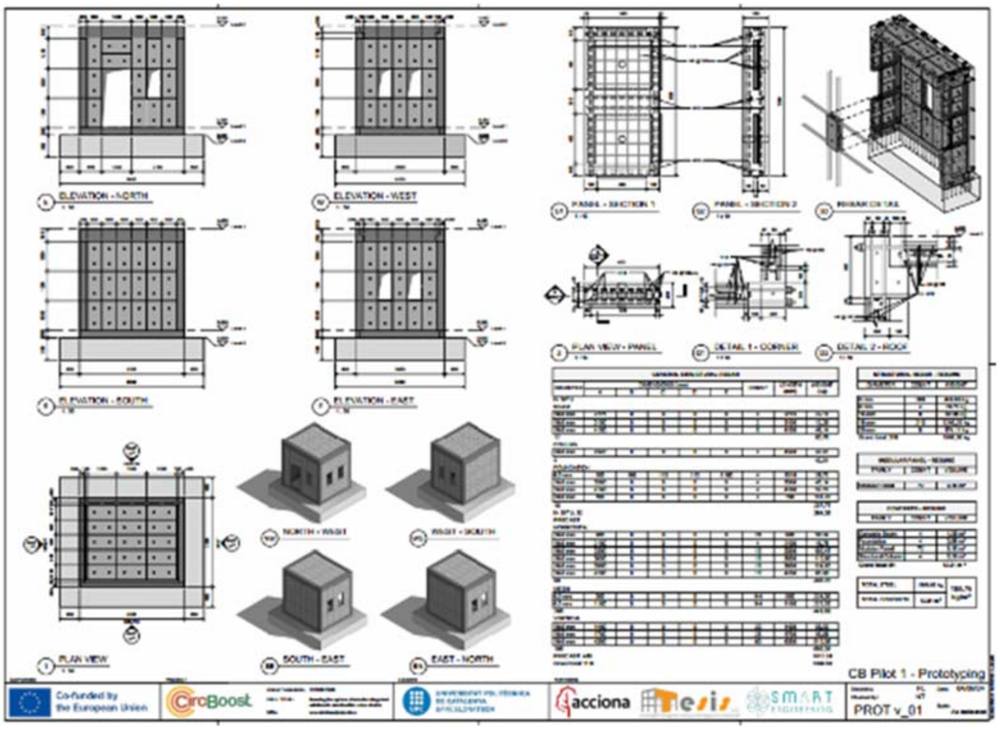
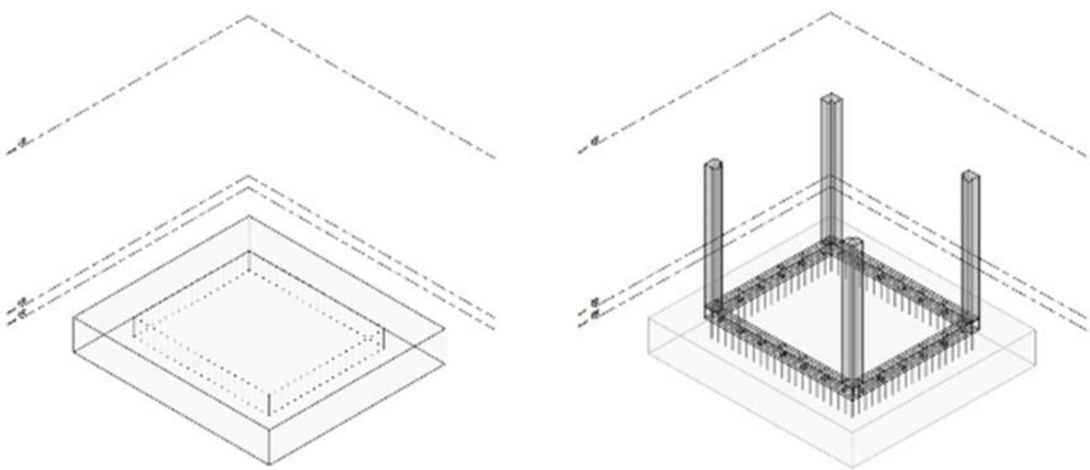
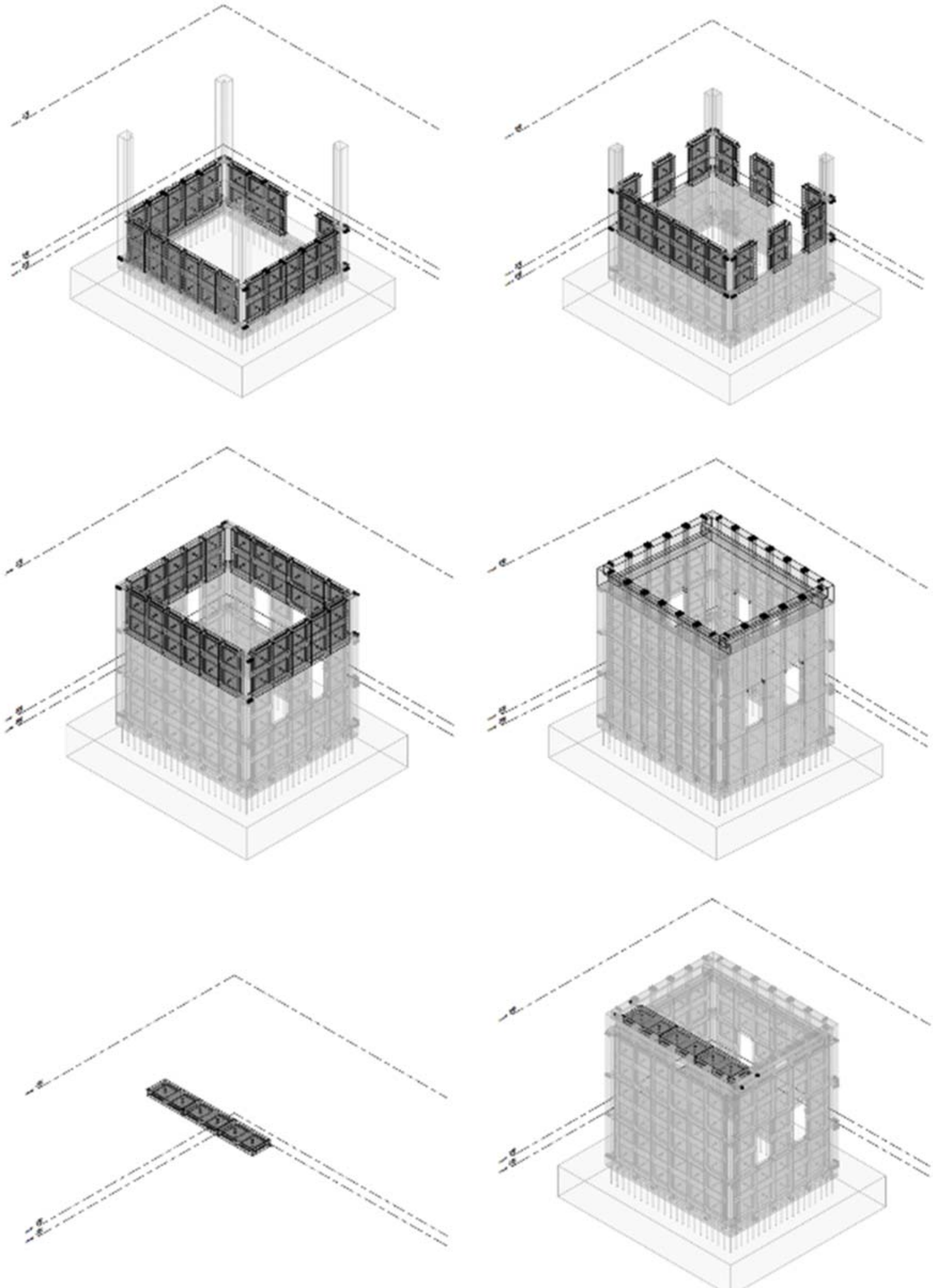


Figure 3.1-16 - Layout of the prototype structure





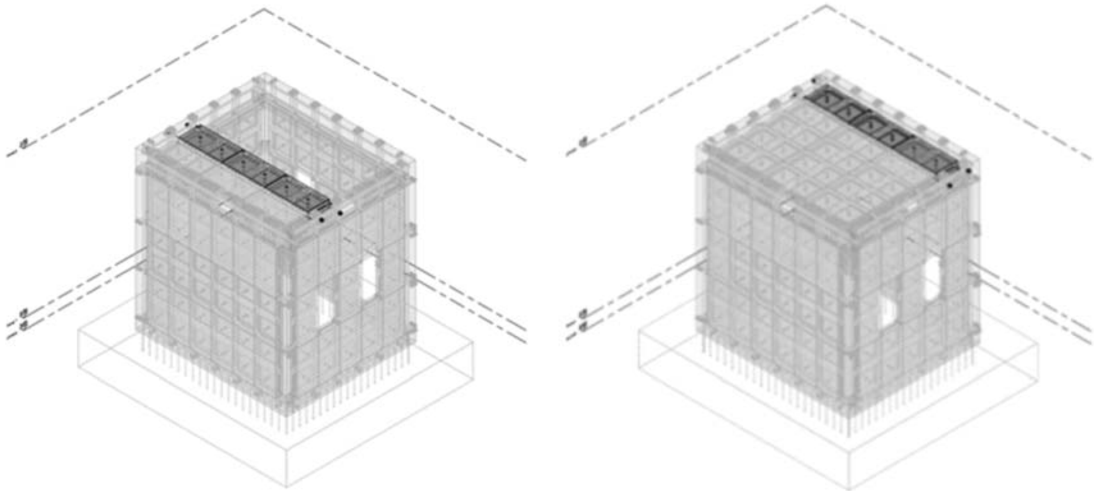
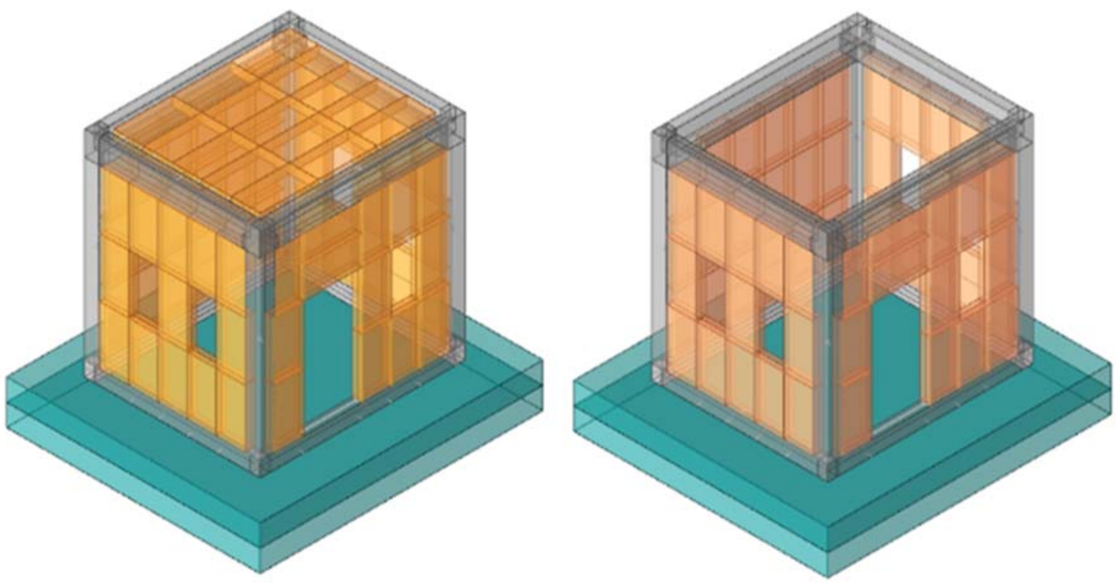


Figure 3.1-17 - Construction procedure of the DfD/R prototype



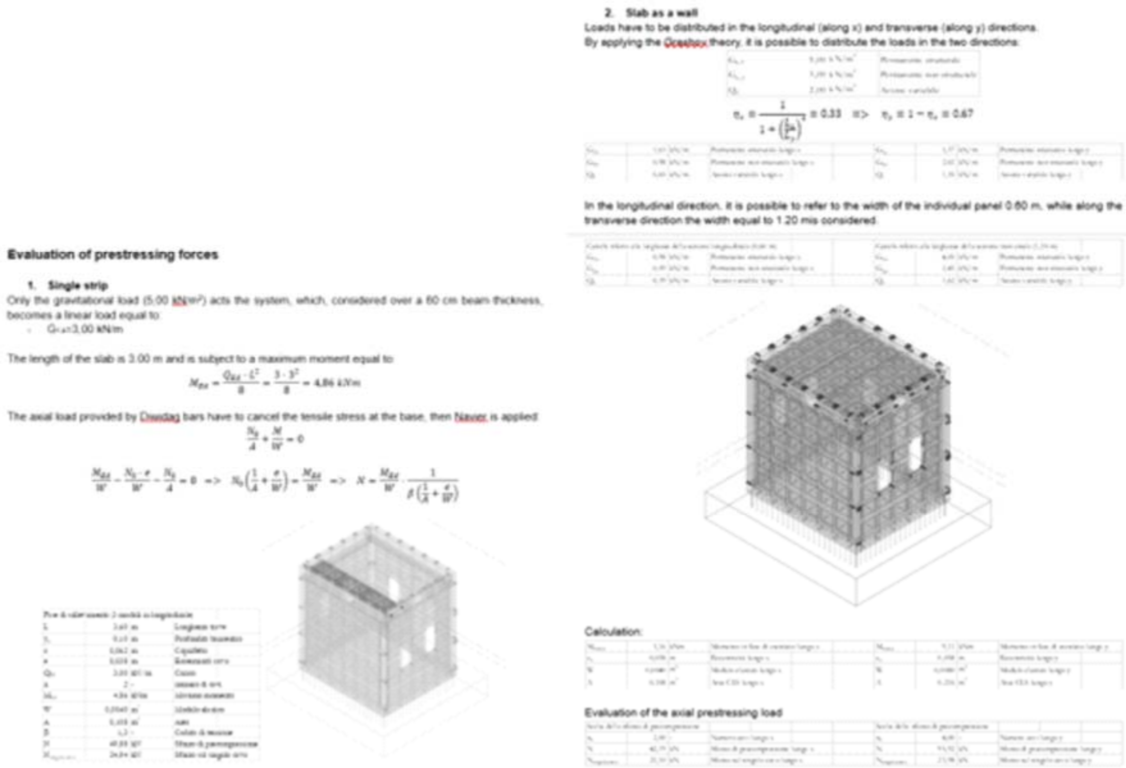


Figure 3.1-18 - Design checks for the prototype structure

T3.4 Pilot's technical evaluation (UPC, ACCIONA, Control Demeter, TESIS, Smart Engineering)

Within this task, a continuous technical assessment was performed of all the activities carried out, as well as the collection of data for other WPs. User experience could still not be assessed as full-scale deployment of the solutions has not yet started.

3.1.3 Progress according to the Pilot operational plan

Considering the timeline for Pilot 1 proposed in the Pilot Deployment Strategy, Figure 3.1-19, until M18 all activities have been on track. Milestone 1 (Pilot Deployment Strategy) was fulfilled on time in M6.

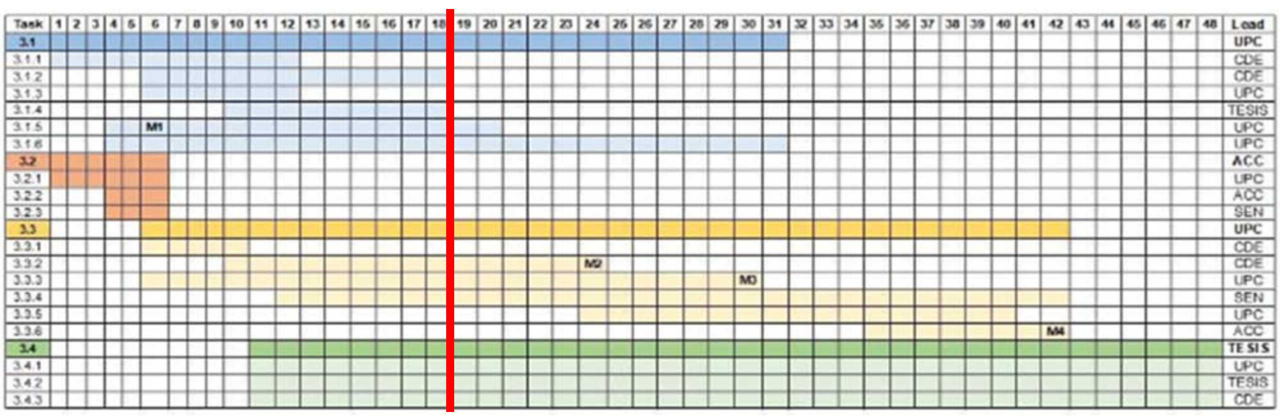


Figure 3.1-19 - Timeline for Pilot 1

As the first year of Pilot 1 implementation was reserved for preparatory and proof of concept activities, the KPIs for pilot implementation have not been evaluated since they are not applicable to the activities carried out in the period M6–M18.

3.1.4 Update of the operational plan (if applicable)

Not applicable to Pilot 1.

3.1.5 Lessons learnt and next steps

The activities of Pilot 1 are running according to schedule and providing expected and acceptable results along all lines of action.

A potential risk for Pilot 1 implementation and deviation from the proposed timeline would be administrative delays in construction permits that could delay the on-site decontamination activities (Task 3.3.2). Envisioned mitigation measures are an allowable delay that allows completion by M42 or the demonstration of decontamination solutions on other sites.

The plan for the following 12 months (M19–M30) for now remains according to the proposed timeline (Figure 3.1-19 - Timeline for Pilot 1).

3.2 Implementation of the Pilot 2 – Paris

3.2.1 Summary

3.2.1.1 Objectives

The overall aim of the pilot is to (i) develop a platform facilitating the matching between supply and demand for materials and waste, allowing for a better identification of construction waste deposits and regional needs; (ii) explore innovative construction processes that enhance the value of materials obtained from deconstruction; (iii) structure the materials and waste upcycling sectors resulting from the deconstruction of buildings.

3.2.1.2 General information about work done in the 1st year

During the first period, the French pilot partnership has been reshaped with the replacement of La Plaine Commune (PCO) by MGP as pilot of the digital platform's POC development in September 2024. The POC was launched in Sept. 2023 and test phases started in Sept. 2024.

Two sites for the physical platform have been identified: an inert and soil waste streams management site (1) and a fixture products reconditioning site (2). This represents the starting point of the pilot deployment regarding the identification of physical platformswhich will then be interconnected with the digital platform, as well as with other existing or future physical platforms located within the territory of the MGP.

As specified in the POP, the aim of the digital tool is to aggregate all materials deposits in the region, and therefore to make visible data from a variety of sources: online marketplaces, online catalogs of physical platforms, public platforms; as well as materials offers and requests put online directly by users. The platform covers all building products, equipment and materials, as well as certain exterior materials (pavers, kerbs, etc.).
As for the innovative functionalities, two reports have been delivered: a synthesis of the recycling platforms' visits with a focus on platform characteristics including technical process (nature of entering and prepared materials); and a state of the art of the environmental evaluation of experimental Eco construction site (E3S, situated in the suburban areas of Paris).

Overall, the pilot is progressing well, but adjustments need to be made to the POP timetable, which at this stage, do not have significant impact on the pilot advancement and expected KPI.

3.2.2 Main activities and results

T3.1 Digital Platform

T3.1.1 Proof of Concept feedbacks (MGP, CSTB) (M6-16)

The Digital Platform POC project has been launched by Plaine Commune in Septembre 2023, with two local authorities within MGP perimeter (Est-Ensemble and City of Paris), through the technical and financial support of MGP. A innovative start-up (Skop) has been selected to develop the prototype platform through a BPI (Public Investment Bank) call for projects.

As specified in paragraph 5.4.2 of D3.1:

In parallel of the CIRCBOOST project, Plaine Commune, a territory of Metropole du Grand Paris is leading the development of a POC - Proof of concept - with the start-up SKOP, within an "AI challenge" launched by the French Public Investment Bank "BPI" and won by Plaine Commune.

The main goal of this POC is to develop and test the following functionalities that have been identified as a priority by Plaine Commune focus on the "territory oriented":

- **Matchmaking tool: Centralize online all the information concerning reuse material available - wherever the data about these materials is** (marketplaces, online catalogues of physical platforms, public platform, ...). Plaine Commune also already owns a lot of data / information, thanks to a data basis that groups all the information about available resources and material needs: ; that will be used to test SKOP digital platform.

- **Centralize online, on the same digital platform, all the information about needs of reused materials**, to enable automatic matchmaking between available and researched reuse materials. All users that look for materials might be able to receive regular updates as soon as a new reuse material that matches their needs is entered in the digital platform

- **Map all this information on a chart,** to be able to visualize all the future projects and localize the nearest reuse materials

During CIRCBOOST project, the goal is to is to build on the work accomplished during the POC and continue to develop the platform by adding innovative functionalities. This development will be based on 3 functionalities)

- Matchmaking platform: Centralize in a digital platform (interoperable meta-platform) all the materials / resources available and demands of reuse and recycled materials and automate a match-making between them

- Indicators calculation: Assess the actions thanks to practical indicators (environmental impact, impact on transportation, jobs created, potential for reuse and recycling, etc.)

- Prediction of flows: Analyze and predict materials and waste flows

Following the completion of the POC (end of March 2025), a first prototype digital platform is now available, fulfilling the functionalities described above.

In order to capitalize on this work, the Metropole has decided to pursue the development of the tool with the same company (SKOP). The contract with SKOP, via an 18 months public innovation contract, will enable the tool to be deployed in the territories, improve existing functionalities and develop new ones.

Two working groups have been conducted (construction sector users and digital marketplace developers) in order to present the project and to precise the technical specifications of the POC Digital Platform.

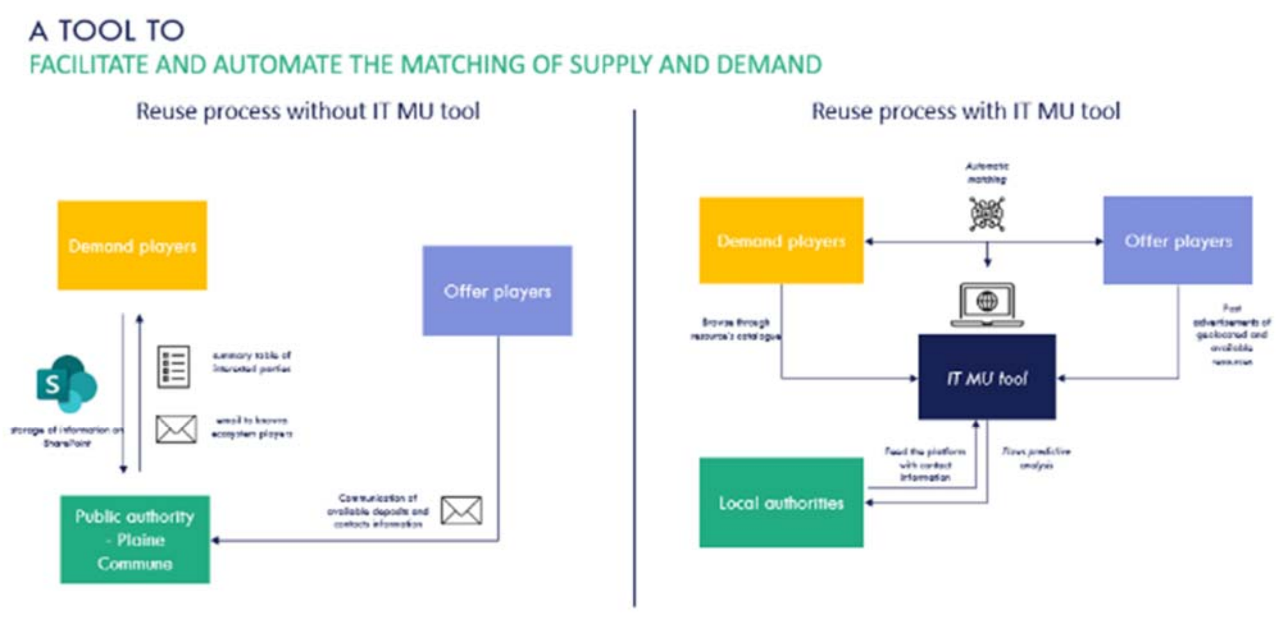


Figure 3.2-1 - Role of the digital platform: facilitating the matching of reused materials

Both of these groups have met twice with two main objectives :

- Precise the digital tool functionnalities needed to be implemented (synthesis below)

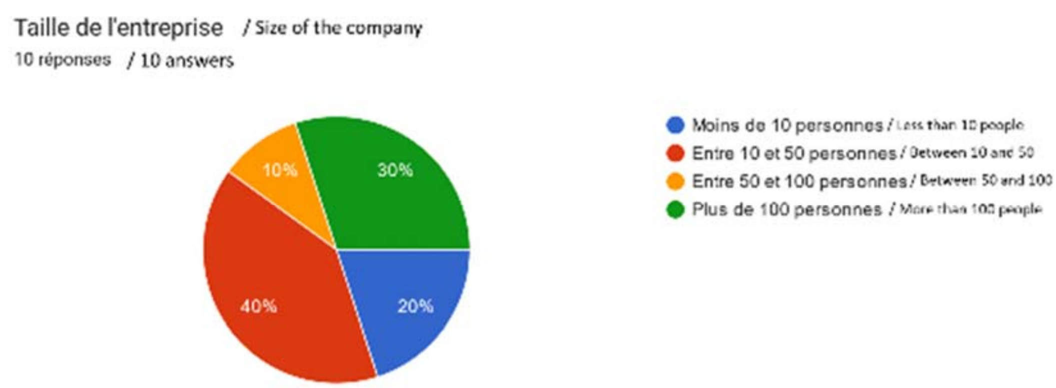
UTILISATEUR	FONCTIONNALITE	COMPLEMENT	MoSCoW
Acteur de l'offre	Publier un gisement	Besoin de caractériser le gisement et sa disponibilité Besoin de photos	Must-Have
Acteur de l'offre	Publier un projet	Afin de spécifier le lieu de collecte du gisement Besoin de ne pas rendre cette info publique	Must-Have
Acteur de la demande	Rechercher un gisement	Utiliser des mots-clés, et des filtres	Must-Have
Acteur de la demande	Visualiser les gisements disponibles	Avoir une vue cartographique des gisements disponibles sur un territoire ; possibilité de filtrage sur ces gisements	Must-Have
Acteur de la demande	Se mettre en relation avec un acteur de l'offre	Obtenir les contacts d'une personne	Must-Have
		Intégrer un système de mise en contact – mailing intégré	Won't-Have
Acteur de l'offre	Modifier le statut d'un gisement	Marquer un supprimé comme acquis	Must-Have
		Avoir des statuts intermédiaires (Réservé...)	Could-Have
Acteur de la demande	Garder des gisements en mémoire	Avoir la possibilité de garder les gisements d'intérêt en 'Favoris' pour pouvoir y revenir plus tard	Should-Have
Acteur de la demande	Créer des alertes sur des gisements recherchés	Recevoir des notifications sur des gisements nouvellement disponibles	Must-Have
Acteur de l'offre	Partager les gisements publiés avec des collègues/partenaires	Ne pas centraliser/personnaliser la gestion de gisements publiés. Faciliter le partage de cette responsabilité	Should-Have
Outils tiers	Publier ces gisements sous IT MU	Passer soit par des APIs, soit par de l'indexation web, pour que des gisements provenant d'un outil donné puissent être publiés sur IT MU.	Must-Have
Outils tiers	Récupérer des demandes de gisements d'outils tiers	Récupérer les demandes/alertes. Si un mail de contact est disponible, remonter la disponibilité de gisements par notification/mail	Could-Have
Outils tiers	Notifier IT MU de l'acquisition de gisements leurs outils, via IT MU	Les outils tiers envoient un rapport régulier (hebdo, mensuel...) à IT MU	Could-Have
		Une API permet aux outils de notifier directement de l'acquisition d'un gisement	Could-Have
Collectivités	Visualiser les effets du réemploi sur leurs territoires	Avoir des indicateurs réguliers (mensuels ? hebdos ? ...) sur le CO2 économisé, km en moins, activités économiques créées... **Besoin de clarifier l'ensemble de ces indicateurs.**	Must-Have
Collectivités	Anticiper les flux de PEM construction sur leurs territoires		Could-Have

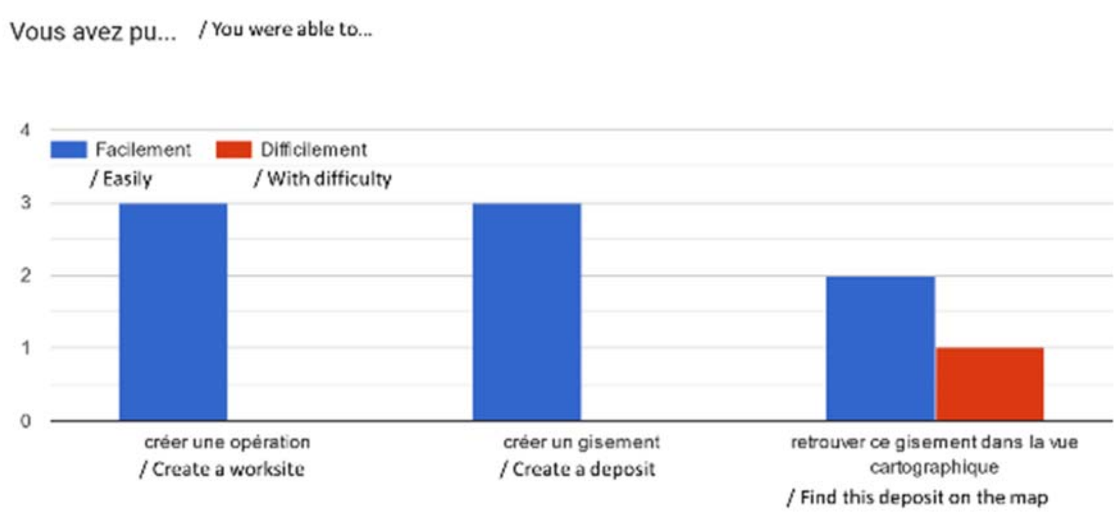
Figure 3.2-2 - Definition of digital platform functions

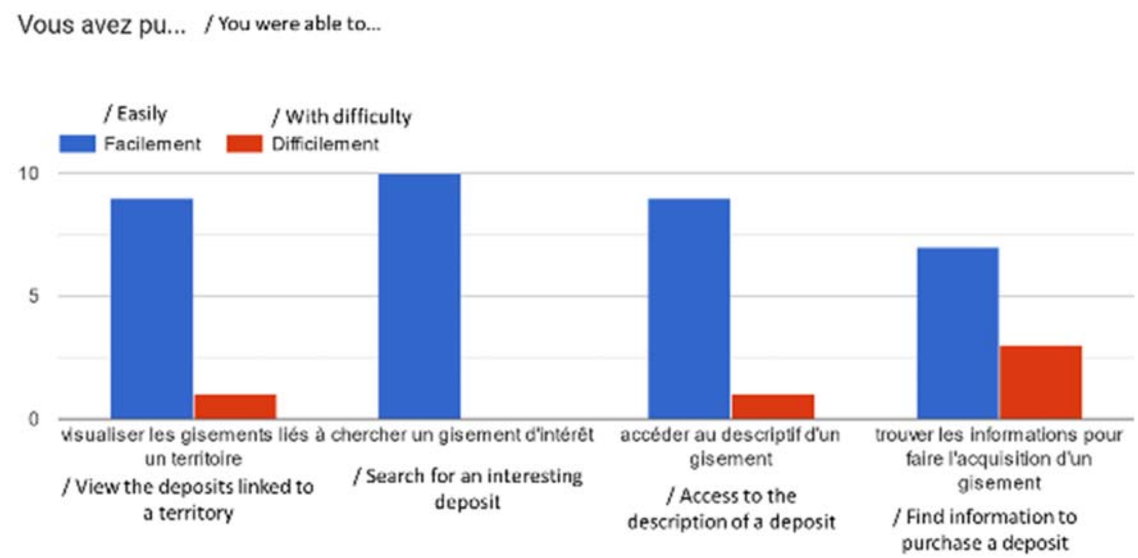
- Validate terms and conditions of cooperation with private marketplaces : the goal of the Digital Platform is to aggregate available data (private marketplaces must agree the scrapping of their data)

3 steering meetings with elected officials have been conducted during the year to validate these specifications.

Due to the IT development time, the test phase of the POC Digital Platform has only started in September 2024 (M16). Several phases of implementation are planned. At the beggining of November 2024 (M18), ten expert organisations have been testing the POC. Some details about these organisations and results of the tests are presented below :







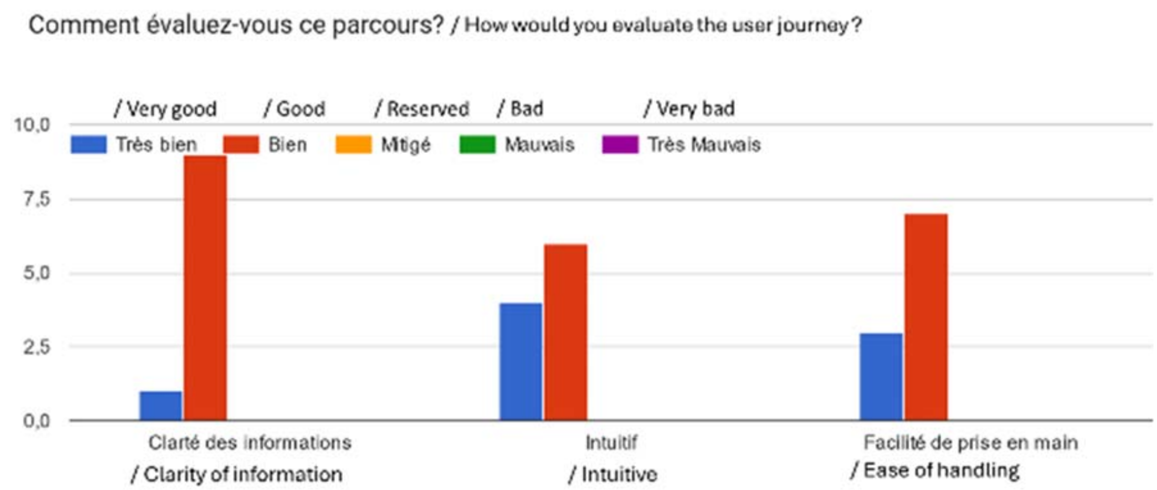


Figure 3.2-3 - First feedbacks from POC users

The POC Digital tool, now named *BTP Match*, will shortly be opened to every construction organizations within the three local authorities perimeter. Here are some of the visuals of the platform :

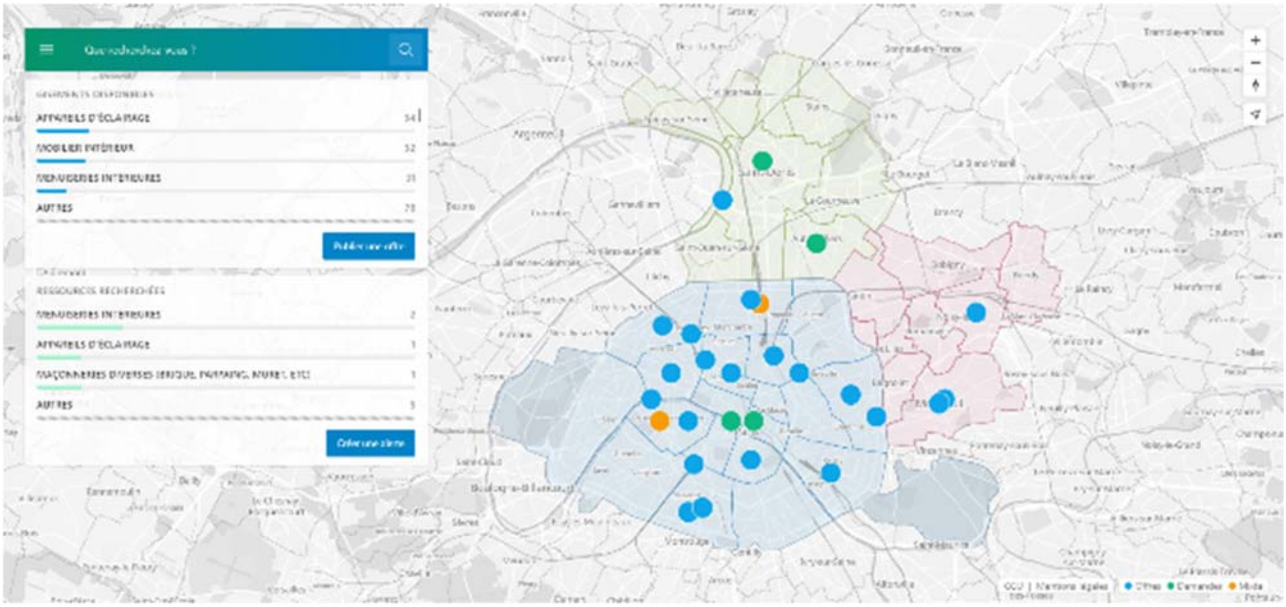


Figure 3.2-4 - Screenshot of the POC digital platform

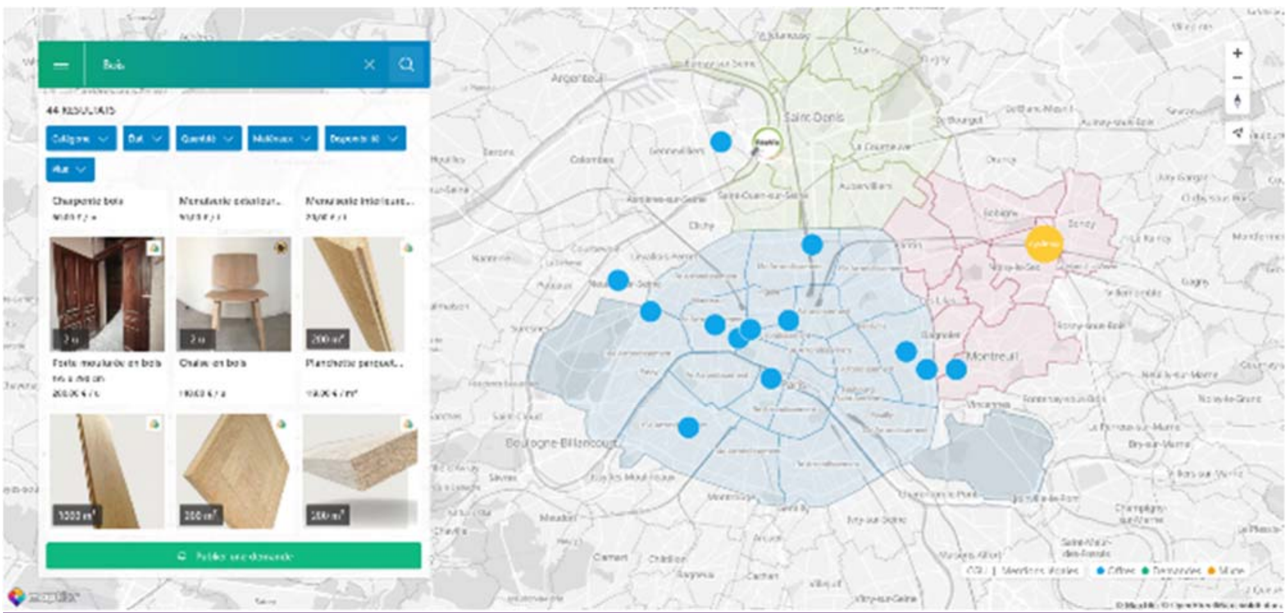


Figure 3.2-5 - Screenshot of the POC digital platform (category selection)

NB: The platform covers all products, materials and equipment for the building industry (finishing materials), as well as certain materials specific to the development of public spaces (bricks, pavers, concrete slabs, etc.).

Regarding development constraints, we propose to extend the duration of the POC until March 2025 (M22) in order to be able to implement all the functionalities needed and to slightly extend the test phase. At the same time, all feedbacks will be gathered in order to build the future platform specifications.

This task needs to be extended until M22, end of the POC. The GANTT has been updated accordingly in section 3.1.4.

Summary of activities:

Partner	Work description
P17. MGP	o Launching of the POC in October 2023 o Implementation of two working groups on specification (users and tool developers) - both of which met twice between October 2023 and July 2024 o 3 steering meetings with elected officials o Start of the test phase in September 2024 o Different phases of implementation (experts, architects, then all project owners) o End of the POC delayed in March 2025 o Implementation of final developments (envisaged as part of the experiment) and extention of the test phase o Gather all feedbacks and adapt future platform specifications
P20. CSTB	CSTB tested the POC after credentials have been shared by MGP to evaluate certain needs or attention points related to the connection of the POC to PEMD platform and to the prediction functionality related to CSTB urban mining tool BTPFlux. The PEMD platform collects all the regulatory diagnoses carried out by developers of demolition and renovation projects subject to the regulations. It enables them to identify specific types of C&DW and resources suitable for recycling and reuse waste suitable for reuse. A connection between BTP Match and this platform would provide an additional data source for displaying reusable materials offers. Another potential integration involves the provision of consolidated regional statistics. CSTB is currently analyzing data from all submitted diagnoses to generate statistics such as the most commonly available reused materials and their respective quantities. This information could be shared with territories using BTP Match to enhance their dashboards. As regards the link between the PEMD platform and the BTP Flux tool, BTP Flux already predicts outflows and inflows of materials in a given area. Connecting the PEMD tool with BTP Flux would make it possible to enhance the applied scenarios related to demolition and renovation activities and their corresponding available material and waste flows add the “reuse” variable: outgoing flows of reusable materials and incoming reused materials. Once connected to BTP Match, this module could forecast the supply of materials from upcoming deconstruction/renovation projects and anticipate future availability of reused materials needs.

T3.1.2 Platform governance (MGP, CSTB, CAP) (M1-M18)

A first important step regarding Platform governance was of a political nature: we needed to ensure the political approval of the transfer of management of the platform project from Plaine Commune to MGP. This transfer, as well as the transfer of Plaine Commune initial actions in CIRCBOOST, has been validated by elected representative.

Role for the Metropole and pilot territories – proposal

Métropole du Grand Paris	Plaine Commune, Paris, Est ensemble
• Steering the development of additional functionalities (continuation of the POC) • Mobilization of an engineering consultant to fine-tune certain topics essential to a definitive tool: governance and economic models, data management, capitalization on feedback from territories • Mobilization of other cities / territories in the process • Maintain link with European project CIRC BOOST	Stay "key users" by : • Promoting the tool in their territory, mobilizing their ecosystems • Contributing to the continuous improvement of the tool: implementation on worksites, feedback on bugs and needs, implementation of shared tools to ensure smooth operation (excel spreadsheets on deposits and research, etc.). • Being involved in the Metropole's reflections on the final tool.

Figure 3.2-6 - Validation of digital platform governance (steering committee)

The final governance model of the final Digital Platform is not yet defined.Three main scenario have been studied at this time (licence, public acquisition of a tool, public-private scenario).

SEVERAL SCENARIOS CONSIDERED FOR THE GOVERNANCE OF THE FINAL TOOL

	Scenario 1 License	Scenario 2 Shared tool between public authorities		Scenario 3 Semi-public company		Scenario 4 Cooperative
		a. Continuation of POC	b. New tool	a. Continuation of POC	b. New tool	
Description	Start-up owns its tool: private platform, local authorities pay a licence fee to use the tool	Public contract to finalize the development of the tool based on the POC which would be bought by the local authorities from Skop (if Skop authorizes it).	Public contract to finalize the new tool using the code from the POC's complementary developments, financed by the local authorities who will own the final tool.	Semi-public company own the POC and the final tool. Contract with SKOP to develop and maintain the final tool. Costs, responsibilities and voting rights are shared between local authorities and SKOP.	Semi-public company own the final tool. Contract with a new start-up to develop the final tool using the code from the POC' complementary developments.	Creation of a cooperative where each member has an equal vote, regardless of their financial contribution (democratic governance) and where the tool code is shared as open source.
Ownership	Start-up (Skop)	Local authorities		Semi-public		Open Source
Initial investment for local authorities	None	High		Moderate		High
Decision-making power of local authorities	Weak	100% owned		Shared (based on the number of shares held by each player in the Semi-public company, and therefore more public than private in nature)		Shared
Summary	Local authorities pay SKOP a long-term license to use the tool, with no initial investment required but no decision-making power either. recommended scenario	Substantial investments to buy the tool (if SKOP authorizes it), complicated governance as numerous public procurements are required. Scenario not recommended	Full autonomy of local authorities over the final tool. Substantial investments to buy back the PC and / or development a new tool, complicated governance as many public procurements are required.	Skop would invest in the Semi-public company via the POC contribution. Shared governance needs to be clearly defined when drafting the articles of association. Flexibility in contract implementation, but potential for "unfair competition", blurring the tool's public service positioning. recommended scenarios	Finding a private company willing to join the Semi-public company and develop the final tool may take some time. Scenario not recommended	A highly innovative model that relies heavily on the commitment of the member community. May pose problems in terms of business model and financing of the tool. Scenario not recommended

Figure 3.2-7 - Long-term economic and governance scenarios

Further investigations need to be done in order to choose the best scenario.

In order to avoid delaying project deployment, we propose to set a transition period of direct contractualization with Skop (through an innovation market).

This task needs to be extended until M28, i.e after the transition period. The GANTT has been updated accordingly in section 3.1.4.

Summary of activities:

Partner	Work description
P17. MGP	o Political approval of the transfer of management of the platform from Plaine Commune to MGP o Transition period after the POC to validate the final platform governance scheme (acquisition, licence, public-private partnership, etc.) o Implementation of an innovation contract during this transition period to enlarge the use of the digital platform (extension to MGP perimeter)
P20. CSTB	Drafting of a position paper addressed to all project partners (May 2024), presenting the PEMD Platform governance and operational model. The purpose of this paper was to assess how the PEMD Platform could fit into the POC development. A working meeting has been arranged in May 2024 with UGE, Sitowie and MGP, in order to discuss the position paper with the consortium and think together about what could be a set of requirements for the digital platform after the POC. Each partner presented the indicators and research they were developing on the circular economy and reuse, to see what potential links could be made in the digital platform. CSTB started to reflect on potential governance conditions related to resource flow prediction functionality which is currently part of BTPFlux tool developed by CSTB. For this purpose, the first discussion took place in October 2024 between BTPFlux product owner at CSTB and MGP and SKOP.

T3.1.3 Matchmaking platform (MGP, CSTB, SIT) (M16-M42)

As the POC period has been slightly delayed, we did not set the final platform specifications at this point. Nonetheless, additional functionalities will be added through a new innovation contract with Skop.

Data Sharing Agreements have been signed with existing private marketplaces in order to ensure the availaibility of their deposis on our Digital Platform.

The assessment of the POC connectability with the PEMD platform, as a matchmaking platform different from a market place, has also been done and results are summarized below.

PEMD stands for “product, equipment, materials and waste” in French. The PEMD platform makes visible some PEMD still in place within existing building sites; these PEMD have not yet been removed or reconditioned. The other marketplaces publish a catalogue of reusable products already available. This is a major difference between the two platforms.

An API from the PEMD platform allows the POC to retrieve the reusable products published on the map: https://platformepemd.developpement-durable.gouv.fr/gisements/

Besides, the product descriptions differ between the POC and the PEMD platform. For example, the POC gives a date to announce when a product will no longer be available. Instead, the PEMD platform provides for some product, a deconstruction or renovation project completion date. In this case, the PEMD will be available only during a part of the project, but this period is not specified.

➔ Reusable products sourced from the PEMD platform on the POC platform should have a distinctive sign, to help users to understand these conditions.

The nomenclatures are also different, but the team in charge of developing the POC has already identified potential solutions, which now need to be confirmed.

Finally, the team in charge of developing the POC must confirm that they have the sufficient budget to carry out these tasks within the scope of the extended duration of the POC.

Summary of activities:

Partner	Work description
P20. CSTB	o Data Sharing Agreement terms set with private marketplaces in order to aggregate their data o Participation to the „digital tool owner“ POC’s working groups (most recent in March 2024) o Working meeting with the POC developer, on the different nomenclatures of products, equipement, materials and waste („PEMD“ in French) used in the POC and the PEMD platform, in order to prepare the link between the digital tools (March-April 2024) o Generation of a document clarifying the features and information available on the visible PEMD posted on the PEMD platform, for the consortium (May 2024) o Working meeting with MGP and de POC developer on the progress of the POC and the API allowing the connection with the PEMD platform (October 2024)

T3.1.7 Engaging end-users (MGP, EIGD, NGE) (M16-42)

As described in T3.1.1, several public and private organisations of construction sector have already been participating in a user working group (about 30 participants) dedicated to define the platform's functionalities.

Below is the list of technical experts (project management assistance for construction projects) that have been testing the POC Digital Platform on real projects: PARIS HABITAT OPH, Tribu Energie, Neo Eco, Cycle Up, REMIX, SETEC, SOLER IDE, ECO+CARBONE, G-ON, Citae

First meetings have been conducted with other local authorities within MGP to ensure diffusion of the Digital Platform within their perimeter.

Summary of activities:

Partner	Work description
P17. MGP	o Construction sector experts on reuse have been associated to the POC o Meetings with other local authorities within MGP perimeter

T3.1.8 Business development (MGP, CSTB, WP6 (M16-42)

This task has not really been started as the POC is still going on. Additional financing needed to develop final Digital Platform is starting to be investigated. Public actors, as Region Ile-de-France, as well as private actors as eco-organisms (Valobat, EcoMinero, etc.) shared their interest and could allocate complementary financing.

The funding allocated to the Metropole du Grand Paris by the European Commission as part of the CIRC BOOST project has enabled the hiring of a person fully dedicated to managing the project during 3 years.

On the other hand, the deployment and development of the digital tool via the 18-month contract with SKOP is self-financed by the MGP.

To ensure the platform's long-term viability, it is therefore necessary to find additional sources of funding to enable the definitive tool to be maintained. The Metropole therefore needs to find a sustainable economic model to ensure the tool's long-term viability in its definitive version - consideration is currently being given to various scenarios and their financial impact and additional sources of fundings by public actors, as Region Ile-de-France, as well as private actors as eco-organisms (Valobat, EcoMinero, etc.) are examined.

The support of WP6 in defining the business model of the platform is also considered as a lever in this search for sustainability.

Partners' contribution

Partner	Work description
P17. MGP	First prospects for additional financing identified

T3.2 Physical Platform

T3.2.1 Model development (EIGD, UGE, MGP) (M1-M19)

Two sites are targeted for the physical platform:

- **Fixture products reconditioning site: T**his site is dedicated to finishing products and equipment in the ultra-urban Île-de-France region. The site would not only be a showroom for reused materials, but would also host workshops for reconditioning materials and conference rooms open to the public and dedicated to the circular economy. We are in the process of signing a letter of commitment with the site owner. This letter of commitment will be signed berfore the end of the year.
- **Inert waste and soil management site:** This site for soil reuse belongs to Eiffage. It is located at Gennevilliers. Here, we will develop the activity of storing inert waste (DI), which will then be sent to Eiffage's recycling platform in Dammartin, before being put back on sale, on the Gennevilliers site, for use by building contractors. Here too, we will secure the implementation of this activity via a letter of intent which will be signed before the end of the year.

Summary of activities:

Partner	Work description
P06. EIGD	Search for land, stakeholders and the platform's business model.

T3.2.2 Platform construction (EIGD) (M14-M31)

This task has not started yet due to the delay in identifying the inert waste and soil management site (initially planned at M13 with construction planned between M14 & M25).

The 2 milestones related to the dentification of both sites (T3.2.1) have been merged with a deadline at M19, meaning that the task starts at M20 with the following timeline:

- *Fixture products reconditioning site:* Preparatory work and operations will start in the first half of 2025.
- *Inert waste and soil management site*: Start of operations is expected between Q1 and Q2 2025.

T3.3 Innovative circular features

Axe 1: Characterization of materials and ways of reuse

<u>T3.3.1 Resource identification</u> (NGE, UGE, EIGD) (M10-M17)

The first year of project focused on existing physical platform process of material preparation. A 6 months internship worked on platforms design and platforms visits (GERS) and delivered a report (MS27) that can be found in Annex 1. Report conclusions are summarized below.

According to the survey (questionnaire) organized among professionnal, the concrete agregates (without the presence of gypsum) are totally consummed for road construction and few building construction incorporated recycled concrete aggregate (RCA) even technically possible and authorized. The production of RCA appeared mainly not enough to cover all the need. The quality of RCA impacts its use. The suspicion of gypsum presence in a truck container induces the rejection of all the truck. A good sorting on demolition site is required and no sorting is operated on platform. A double flux of material transport is systematically applied for earth (earth are mainly not valorized except on platform associated to earthworkers (most of platform owners are not specialist of recycling but complete their activities of concrete manufacturer, quarrymen, construction builders, earthworkers...). Earths are used to fill quarry and natural agregates from the quarry comes to complete the proposed materials on platform (double flux to optimize transport). From observation on entering and valorized materials and considering the poor interest brought to earth (and fine materials), the second year of project will be dedicated to the characterization of earth and how to optimize their valorization (to anticipate the possible regulatories evolution if the filling of quarry is not considered as a way of reuse).

Two internships will be conducted from march 2025 to september 2025 on ressource identification (to complete first internship), and on characterisation methods to validate the listed ways of reuse.

A prolongation of the task until M31 (December 2025) is needed. The visit of platform will continue to be organized in 2025 to complete the global view of platform design, their mapping (localization, competition, need of new platforms...) and to identifiy the new or innovative process (tools) developped or implemented and their potential. Especially, the captors to collect data on platform will be observed if present. Indeed mainly no captor except a connected balance for truck and cameras are positionned on platform. Home made basic software are mainy present for traceability and to send to eco-organism the material quantities for payment (French system). Captors for material characterisation (ie gypsum detection) that impacts on agregates quality, captors for environmental characterization for earth for example (based on hyperspectral camera and other technology) are not applied.

Summary of activities:

Partner	Work description
P10. UGE	6 months internship (MS27) on platforms design and platforms visits (GERS)

Axe 3: Environmental impact using indicators

<u>T3.3.6 Environmental analysis and LCA</u> (UGE, SIT) (M10-M30)

UGE / COSYS : State of the art and reassessment of the environmental evaluation of experimental Eco construction site (E3S, situated in the suburban areas of Paris).

The research programme is structured around the following themes:

- Methodology for quantifying construction and public works flows
- Evaluation and monitoring of circular economy strategies
- Evaluation of solutions on real construction site cases, from an environmental point of view, using ISO 14001,
- Prospective of the circular economy based on the construction of scenarios (construction variants using structural existing parts, more or less recycled concrete aggregate….

This work contributes to understanding the challenges of the circular economy, including the mobilization of waste as a resource, transportation, as well as the storage and treatment of waste from deconstruction projects. Although environmental assessment is highly standardized, predicting impact scores when proposing alternatives remains difficult, and the significance of various construction choices is still not well understood.

We studied an existing deconstruction-reconstruction site than has been used as a research case since the deconstruction phase (E3S). It has now become a living urban area. The study has been carried out using complete life cycle analysis integrating the deconstruction phases, the management of excavated material and resources and their mobilization within the project (based on real dataset).

At each phase, possible variants must be evaluated on the basis of the ISO 1400 standard. For example, the following aspects could be considered: reducing the amount of reinforcement and adjusting concrete formulations, using recycled concrete aggregates and reusing reusable structural elements such as slabs, columns and wood.

The lifespan of theses solutions, including their intended use and the duration of the operation (including maintenance) will also be an integral part of the assessment, even though lifespan considerations are not currently regulated.

The objective of this work is to adopt an approach that prioritizes environmental impact over other criteria, particularly project cost.

Fictitious alternative (reconstruction) scenarios can therefore be developed and evaluated.

Several existing environmental assessment software programs can also be used and compared as part of this study (including an in-house program and OpenLCA). The identification of the materials database used on this experimental construction site was conducted, using DIOGEN-CIOGEN database (from AFGC “Association Français de Génie Civil”) and INIES. The report serves as an application of standards and the state of the art, specifically applied to E3S and proposes:

- Modelling environmental impact using LCA tools for construction phases and material choices, comparing conventional construction with an experimental building maximizing recycled concrete materials, and evaluating alternative reuse-based scenarios.
- Comprehensive environemental impact analysis considering life span of buildings (40 years),
- State of the art research aimed at providing a comprehensive analysis of the spatial dynamics of these urban areas up to 2050 and beyond. This includes models of various factors influencing urban environmental impacts, as well as the evaluation of urban transportation, urban metabolism and key characteristics of dense areas.

The report can be found in Annex 2.

All these approaches will feed a forecasted urban dynamic model to evaluate environmental impacts of urban areas, including carbon footprint. This will be developed in next step related to the platform deployment.

Research activities will later focus on the methodology for environmental evaluation using Life Cycle Analysis open tools (OpenLCA) and propose optimization mathematical tools to assess socio-economic and environmental impacts over a 40-year lifespan in dense urban areas. It will focus on the specific cases of the physical platforms. This advanced modelling will primarily focus on urban mobility, maintenance of buidings (for various scenarios), and urban metabolism, including water. The research is ongoing with completion expected by the end of 2025.

Summary of activities:

Partner	Work description
P10. UGE	6 months internship (MS32) on environemental evaluation of sustainable suburban areas (COSYS)

T3.3.7 Scenarios for use of materials [UGE] SIT (M10-M41)

The reassessment of the environemental impact (including carbon impact) on the E3S urban areas delivered that transportation of materials and mobility of inhabitants is a major issue. Moreover, in dense cities, the question of the use of earth and geomaterials is necessary to minimise intrants. The research will focus on a case given by the physical platform if possible (depending on the project). It will study scenarios that optimise the reuse of materials, including geomaterials. The methodology will be proposed to evaluate alternative scenarios, taking the example of historical architectures and trying to propose alternative construction technics, using mixt constructive solutions. These theoretical exercises will question the optimisation of different mathematical tools to estimate the different flux involved in the dynamic global model for urban areas.

Partners' contribution

Partner	Work description
P10. UGE	12 months research post-doctoral fellow

3.2.3 Progress according to the Pilot operational plan

Table 3.2-1 - Pilot 2 Milestones

#	Milestone	Month	% of fulfilment	Comment
6	Digital platform – POC completion	16	80%	Postponed to M22
7	Digital platform – Choice of governance	18	50%	Postponed to M28
20	Physical platform - End of conception phase for inert waste and soil management site	13	63%	Merged with MS21 due at M19
27	Axe 1: Characterization of materials and ways of reuse – Milestone 1	17	100%	Delivered at M17. An updated version (MS27 V2) will be supplied in December 2025.
32	Axe 3: Environmental impact using indicators – State of the art	17	100%	Delivered at M17

3.2.4 Update of the operational plan

Updates are in yellow in the plan.

	2023							2024												2025				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tasks	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fev	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
T1 Pilots operation plan and evaluation methodology (M1 - M42)																								
T1.1 Pilot Operational Plan				1																				
T1.2 Evaluation methodology				1																				
T1.3 Pilot year report																		3						
T2 Establish pilot baselines (M1-M6)																								
T2.1 Physical Platform						2																		
T2.2 Digital Platform						2																		
T3 Pilot deployment (M6-M42)																								
T3.1 Digital Platform																								
T3.1.1 Proof of Concept feedbacks																~~6~~						6		
T3.1.2 Platform governance																		~~7~~						
T3.1.3 Matchmaking platform																				~~8~~				~~9~~
T3.1.4 Prediction module																								
T3.1.5 Indicators module																								
T3.1.6 Interoperability with PEMD Platform																								
T3.1.7 Engaging end-users																								
T3.1.8 Business development																								
T3.2 Physical Platform																								
T3.2.1 Model development (inert waste and soil management site then reuse site)													~~20~~						20 ~~21~~			21		
T3.2.2 Platform construction (inert waste and soil management site then reuse site)																								
T3.2.3 Recycling lines operation																								
T3.2.4 Reuse zone implementation																								
T3.2.5 Interoperability with the digital platform																								
T3.3 Innovative circular features																								
Axe 1: Characterization of materials and ways of reuse																								
T3.3.1 Resource identification																	27							
T3.3.2 Resource characterization																								
T3.3.3 Characterization and formulation of eco-materials																								
Axe 2: Waste quantities (flow), logistic, environmental and economic aspects																								
T3.3.4 Recovery routes identification																								
T3.3.5 Material flows optimization																								
Axe 3: Environmental impact using indicators																								
T3.3.6 Environmental analysis and LCA																	32							
T3.3.7 Scenarios for use of materials																								
T3.4 Pilot deployment coordination																								
T3.4.1 French pilot monthly meetings																								
T3.4.2 Pilot leader monthly meetings																								
T3.4.3 Biannual reporting																								
T4 Pilots' technical evaluation (M12-M45)																								
T4.1 Pilot performance assessment																								
T4.2 Technical performance assessment																								
T4.3 Value for users' assessment																								

	2025							2026												2027				
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Tasks	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
T1 Pilots operation plan and evaluation methodology (M1 - M42)																								
T1.1 Pilot Operational Plan																								
T1.2 Evaluation methodology																								
T1.3 Pilot year report						4												5						
T2 Establish pilot baselines (M1-M6)																								
T2.1 Physical Platform																								
T2.2 Digital Platform																								
T3 Pilot deployment (M6-M42)																								
T3.1 Digital Platform																								
T3.1.1 Proof of Concept feedbacks																								
T3.1.2 Platform governance				7																				
T3.1.3 Matchmaking platform				8		9 & 10																		
T3.1.4 Prediction module								12										13						
T3.1.5 Indicators module								14						15		16		17						
T3.1.6 Interoperability with PEMD Platform																		18						
T3.1.7 Engaging end-users																								
T3.1.8 Business development																		19						
T3.2 Physical Platform																								
T3.2.1 Model development (inert waste and soil management site then reuse site)																								
T3.2.2 Platform construction (inert waste and soil management site then reuse site)	22						23																	
T3.2.3 Recycling lines operation													24											
T3.2.4 Reuse zone implementation																								
T3.2.5 Interoperability with the digital platform						25												26						
T3.3 Innovative circular features																								
Axe 1: Characterization of materials and ways of reuse																								
T3.3.1 Resource identification							27 (V2)																	
T3.3.2 Resource characterization							28																	
T3.3.3 Characterization and formulation of eco-materials																	29							
Axe 2: Waste quantities (flow), logistic, environmental and economic aspects																								
T3.3.4 Recovery routes identification							30																	
T3.3.5 Material flows optimization																	31							
Axe 3: Environmental impact using indicators																								
T3.3.6 Environmental analysis and LCA						33																		
T3.3.7 Scenarios for use of materials																	34							
T3.4 Pilot deployment coordination																								
T3.4.1 French pilot monthly meetings																								
T3.4.2 Pilot leader monthly meetings																								
T3.4.3 Biannual reporting																								
T4 Pilots' technical evaluation (M12-M45)																								
T4.1 Pilot performance assessment																								
T4.2 Technical performance assessment																								
T4.3 Value for users' assessment																								

3.2.5 Lessons learnt and next steps

Task	Unforseen risk
T3.2.1 Model development (Physical Platform)	There is one risk linked to the acquisition of the fixture products reconditioning site. If the site is not secured, we should search for another site and that may delay the work.
T3.3.1 - Resource identification	The implementation of the Circ-Boost physical platform by EIGD will bring new opportunity to identify ressources. Some materials (mix of material, organic materials...) not identified until now may be added to the panel of studied materials if their reuse appear as an interesting challenge for future.

3.3 Implementation of the Pilot 3 – Belgrade

3.3.1 Summary

At the end of year one, the following essential tasks have been completed: architectural and conceptual structural design, detailed structural design, creation of a database of potential sources for recycled and reusable materials, procurement of equipment and materials, as well as numerical prototyping and testing.

3.3.1.1 Objectives

This pilot objective is to demonstrate the possible application of low-carbon and resource efficient structural solutions and materials that can be sustainably applied in the Balkan region construction practice with a focus on their circularity. This will be done by building the ground floor house that can be easily assembled and disassembled, and testing it in the operational environment.

The objective of Pilot 3 is to enhance the deployment and market adoption of innovative low-carbon and resource-efficient circular solutions in the Serbian construction industry, with a particular focus on activities supporting this goal. In the first year, a one-day seminar titled A Step Toward a Carbon-Neutral and Circular Construction Industry was organized for key target groups, including researchers in sustainable construction, construction waste treatment companies, precast concrete companies, steel companies, architectural and design bureaus, and investors. The event was attended by 60 participants in person and 12 online.

The structural design of house elements was carried out in collaboration with industry partners to develop low-carbon and resource-efficient solutions suitable for industrial application. These include reusable and modular structural elements, concrete with 100% coarse recycled aggregate, high-volume fly ash concrete, reused steel, reused brick for infill walls, and recycled rubber for seismic isolation. A comprehensive sustainability evaluation of these solutions will be conducted for a pilot house as a whole, in collaboration with WP5. This process has already begun with the preparation of local inventory data required for life cycle assessment analysis.

3.3.1.2 General information about work done in the 1st year

M1-M4 - In the first four mounts of project implementation focus was put on introductory meetings (within FCE, with pilot's partners and potential end-users/stakeholders). Introductory meetings for projects members within FCE were organized for all staff groups (administrative, financial, technical, organizational). Individual meetings with all partners related to pilot project (PENTA, EBR and SDA) were organized to make an initial plan of actions for the first year and means of communication. One set of meetings was organized with key stakeholders to define relevant project aspects according to their needs.

M5-M7 - In the next three mounts focus was on the house design. First, an architectural house design was done to produce functional, practical, modular and sustainable space facilitated in 3R Pilot house. Based on obtained architectural design, a conceptual structural house design was made.

M8-M18 - The next eleven months were firstly dedicated to detailed structural design of the 3R Pilot house. This task was conducted in close collaboration with project partners to ensure optimized design and implementation of best practical solutions in the design. Parallel to detailed house design, sustainable materials for the construction were obtained. Research of local market for recycled and reused materials was done, and the database of potential sources was made. Based on conducted research, material procurement of recycled concrete aggregate, recycled brick and reused steel was done. After initial characterisation of recycled concrete aggregate, design of concrete mixture made with 100% of coarse recycled concrete aggregate was made. Experimental testing of various mix designs was done to get the optimal concrete design for house reinforced concrete elements.

Verification of Pilot 3 house in operational environment requires a systematic approach and testing at all levels. Majority of basic equipment needed for those tests is available at the FCE laboratories, and missing equipment was planned in the project budget. Major equipment needed for prototype testing was purchased in this period, and training for FCE employees was performed.

The house detailed structural design was together with partners in an iterative process: analytical design-practical evaluation-testing-analytical design. Detailed design of rubber connection was also done based on the displacement calculation of the house overall model. This was later used for defining the drawings and needed amounts of rubber strips (INODIS connection). Preliminary prototype testing was done numerically to get the first guidelines for detailed design and experimental setup. All structural elements of 3R house were analysed, and detailed drawings (formwork, reinforcement, details) of all elements were made. Detailed setup for experimental testing of all elements was made for frame structures and columns.

3.3.2 Main activities and results

TASKS 1 - Pilot operation plan and evaluation methodology and TASK 2 – Establishing pilot baselins (FCE)

The first 6 months of the project implementation was focused on pilot operational planning (T1.1), state-of-art for each solution (T2.1), establishing baselines (T2.3) and evaluation methodology (T1.2). This was all defined and summarized in the D3.1 Pilot Deployment Strategy (M6). Also, during this period, initial meetings within Faculty of Civil Engineering team and with project partners and key stakeholders were organized. Pilot operational plan included organization and definition of subgroups needed for effective implementation of the whole project. Responsible members for the following activities were assigned: administration, finances, other work packages contacts (WP2, WP6, WP7, WP8) and sub-teams within pilot technical aspect (concrete, connections, steel, rubber and brick) were formed. Individual meetings with all partners related to pilot project were organized to make an initial plan of actions for the first year and means of communication (T2.2). Initial meeting with project partner PENTA was organized to define steps from material acquisition, formwork and concrete production, general concept of all reinforced concrete elements to house assembly. The first visit to PENTA factory was also organized during this period.

Figure 3.3-1 - Penta Ge.Co. precast factory visit, October 2023, Smederevska Palanka

Initial meeting with ERB was organized to define steel acquisition and production of reused steel elements and details for connection. Meeting with SDA was organized to define the strategy for the application of recycled rubber strips (INODIS connection) within the Pilot 3 house. Company REGUPOL joined the meetings, since they will produce recycled rubber strips and deliver them as a donation to the Circ-Boost project.

One set of meetings was organized with key stakeholders and end-users to define relevant project aspects according to their needs. The first meeting was organized with Peikko company, supplier of connection technology for precast and cast-in-situ construction. The main aspects of CircBoost project and a detailed idea of Pilot R3 house were presented to Serbian representative of Peikko company. Demountable connectors for the connection od concrete and steel elements within Pilot 3R house were selected from their assortment. Peikko company was selected as one of the world's leading producers of demountable connections for precast elements. Their representative expressed a great interest in Pilot 3R house testing and demonstration. The next set of meetings was conducted with sustainable construction material producers. This was also done as a market research work needed for task T3.4 *Database of potential sources of recycled and reusable materials*. Meetings were organized with one demolition company from Novi Sad (Šuša Company), one regional construction and demolition waste treatment facility (Beo čista energija doo) and two companies that have reused steel (Iva Procesna Oprema from Aranđelovac and GRAPPS from Smederevo). These meetings were organized to find possible sources of recycled and reused material for the production of Pilot 3R house. One introductory meeting was organized in this period with Serbian Green Building Council to define an initial strategy for key stakeholder list.

An initial plan for Pilot 3 implementation was made for D3.1 Pilot Deployment Strategy in M6. After initial meeting within FCE, with project partners and key stakeholders and after initial market research regarding equipment procurement, new Timetable was made in more details, with adequate subtasks and necessary changes in regard to Pilot Operational Plan Timetable (shown below). In the following text the tasks designation will be in accordance with those in the Table 3.3-1.

Table 3.3-1 – Updated list of Pilot 3 tasks and activities

M1-M5	T1	Pilots operation plan and evaluation methodology (M1 - M4)
M1-M4	T1.1	Pilot operational plan
M4-M5	T1.2	Evaluation methodology
M1-M7	T2	Establish pilot baselines (M1-M7)
M4-M5	T2.1	SoA for each solution
M1-M4	T2.2	Initial meetings with pilot's partners and potential end-users and stakeholders
M5-M6	T2.3	Establishing baselines
M6-M7	T2.4	Comaprison between pilots
M1-M42	T3	Pilots deployment (M6-M42)
M1-M21	T3.1	Equipment acquisition and deployment
M4-M7	T3.2	Architectual design of the house and conceptual structural design
M8-M28	T3.3	Detailed structural design together with partners
M8-M20	T3.3.1	Design of concrete columns, walls and foundations for prototype testing

M17-M28	T3.3.2	Design of composite slab
M17-M18	T3.3.3	Design of rubber connection for infill walls for prototype testing
M14-M17	T3.3.4	Design of demountable joints for prototype testing
M9-M18	T3.4	Database of potential sources of recycled and reusable materials
M6-M25	T3.5	Material procurement (RCA, fly ash, recycled rubber, connectors and other) and concrete design
M6-M13	T3.5.1	Recycled concrete aggregate-RCA
M21-M25	T3.5.2	Fly ash
M10-M19	T3.5.3	Old/used bricks
M22-M25	T3.5.4	Recycled rubber
M18-M21	T3.5.5	Connectors
M13-M17	T3.5.6	Reclaimed steel components for reuse
M15-M22	T3.5.7	New steel sections and profiled steel sheeting
M16-M19	T3.5.8	Recycled aggregate concrete-RAC casting and testing
M23-M29	T3.5.9	Fly ash concrete-FAC casting and testing
M10-M40	T3.6	Production of prototype
M17-M22	T3.6.1	Formwork production and reinforcement instalation
M10-M21	T3.6.2	Numerical prototype simulation of pilot house elements
M22-M24	T3.6.3	Sample casting at Penta - part 1: NAC columns
M24-M26	T3.6.4	Sample casting at Penta - part 2: RAC columns
M27-M34	T3.6.5	Production of frame prototype (made of 2RAC columns and one steel beam and bottom beam)
M25-M34	T3.6.6	Production of infill walls
M18-M21	T3.6.7	Moment-resisting joint prototype fabrication
M23-M25	T3.6.8	Column base joint prototype fabrication
M23-M30	T3.6.9	Composite slab-to-steel beam connection

M24-M41	T3.7	Production of house elements
M25-M40	T3.7.1	RC columns, walls and foundations
M24-M40	T3.7.2	Steel frame elements
M34-M39	T3.7.3	Composite slab on the profile steel sheeting with FAC
M28-M36	T3.7.4	Infill walls
M36-M39	T3.7.5	Floor slab
M36-M43	T3.8	House construction
M1-M48	T3.9	Demonstration and promotion activities
M12-M45	T4	Pilots' technical evaluation
M12-M34	T4.1	Prototype testing
M12-M21	T4.1.1	Numerical testing of house prototype
M17-M28	T4.1.2	Development of the test set-up
M18-M23	T4.1.3	Small scale tests on brick/concrete/steel/rubber connection
M19-M22	T4.1.4	Trial testing of the equipment
M23-M25	T4.1.5	Testing of NAC columns
M24-M26	T4.1.6	Analysis of the results for NAC columns
M25-M34	T4.1.7	Testing of RAC columns
M27-M36	T4.1.8	Analysis of the results for RAC columns
M27-M37	T4.1.9	Testing of RAC frames
M28-M39	T4.1.10	Analysis of the results for RAC frames
M30-M39	T4.1.11	Testing of infilled frames
M32-M40	T4.1.12	Analysis of the results for infilled frames
M19-M22	T4.1.13	Testing of moment-resisting beam-to-column joints, Data processing
M22-M24	T4.1.14	Numerical simulations, Parametric studies, Data analysis for moment-resisting beam-to-column joints
M24-M26	T4.1.15	Testing of column base joints, Data processing

M27-M29	T4.1.16	Numerical simulations, Parametric studies, Data analysis for column base joints
M28-M35	T4.1.17	Composite slab-to-steel beam connection demonstration
M30-M40	T4.1.18	Result discussions and final Conclusions
M37-M45	T4.2	In-situ testing of house and its elements
M38-M43	T4.3	House assembly and dissasembly
M12-M45	T4.4	"Horizontal" activities through the other WPs

TASK 3 PILOT DEPLOYMENT, M6-M42.

Task T3.1 Equipment acquisition and deployment (FCE), M1-M21

Verification of Pilot 3 house in operational environment requires a systematic approach and testing at all levels. Majority of basic equipment needed for those tests is available at the FCE laboratories, and missing equipment was planned in the project budget. Market research was conducted for pieces of the equipment. All equipment that is a part of Circ-Boost budget is needed for prototype experimental testing (from M23) and in-situ house testing (M37).

The main piece of equipment is a 3D digital image correlation in-situ measuring system needed for comprehensive tracking of dilatation (displacement) during experimental testing in the laboratory and in operational environment. Procuring a 3D digital image correlation system was completed in January 2024, M8. The optical measurement system in question is X-Sight 3D DIC M16 and was supplied by Shidamzu's branch in Serbia. The 3D DIC kit includes two low-noise 16 MPx cameras with two sets of low-distortion lenses and three sets of LED lights for various measurement areas, calibration grids, mounting accessories, auxiliary devices for connection of the system with external testing machines and sensors and APLHA DIC software operating in real-time and post-processing mode. Faculty of Civil Engineering, Shimadzu, and X-Sight representatives organised a training on the X-Sight DIC 3D system attended by Circ-Boost participants from FCE Belgrade. The participants had an opportunity to participate in tensile tests, a four-point bending test of a reinforced concrete beam and a load test of the steel frame. Some pictures from this training are shown below.

Figure 3.3-2 - X-Sight DIC 3D system training at the FCE in M8

Next piece of equipment needed for prototype testing of out-of-plane load capacity of walls are airbags. They were delivered in April 2024, M11. Six 1×1m^2 airbags, along with inflation accessories, were made and supplied by Pronal, France. The chosen type of airbags, made of nitrile PVC, have sufficient load capacity, spread the load evenly, have good abrasion resistance, and are light and easy to handle. Some figures of acquired airbags are shown below.

Figure 3.3-3 - Pronal Airbags, Faculty of Civil Engineering, April 2024

The vibration actuator–electrodynamic shaker set by SPEKTRA GmbH Dresden is delivered in October 2024. The APS Dynamics APS 400 ELECTRO-SEIS shaker is a long-stroke, electrodynamic force generator designed for modal excitation of various structures, particularly when low frequencies are required. The accompanying vibration controller system provides harmonic and random excitation. The system will be delivered with reaction mass assembly to mount it on the structure and use it as an inertial shaker. In the future, the APS 400 shaker can be upgraded with an excitation stinger kit to be used as a modal shaker or as a shaking table with an auxiliary kit. The TRC PRO, Serbia, will supply the shaker set.

Figure 3.3-4 - Vibration actuator–electrodynamic shaker

The procurement of load cells for the reaction wall and vibration sensors–accelerometers is ongoing. The procurement of load cells for the reaction wall and vibration sensors-accelerometers is ongoing. Public procurement of these pieces of equipment is in process. It is expected to be completed in January 2025, M20. The load cells in question will be used to measure the surface load applied by airbags during the out-of-plane tests (from M30). The low-noise accelerometers will be used for ambient and forced vibration tests in house in-situ testing (from M37).

T3.2 Architectural design of the house and conceptual structural design (FCE), M4-M7

The first step in the designing process of Pilot 3R house was a conceptual architectural design. The main aim was to produce functional, practical, modular and sustainable space facilitated in 3R house. In the figure below a progress from proposal idea to first draft of real 3R house is shown.

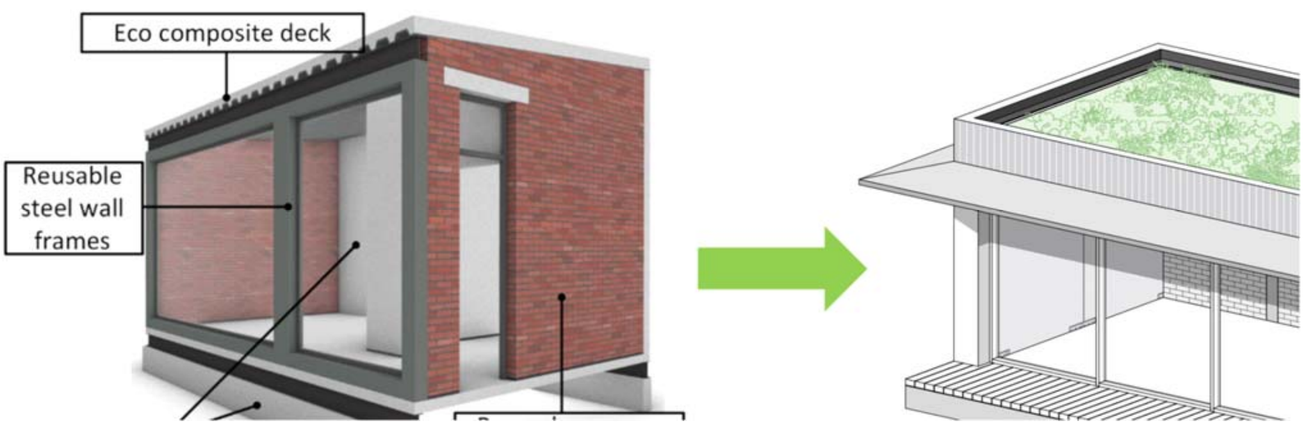


Figure 3.3-5 - 3R Pilot house from the initial idea (left) and the first draft of real 3R house

Architectural design firstly analysed modularity of this house, and adopted a modular block of 150x150 cm. Modularity options are shown in figures below.

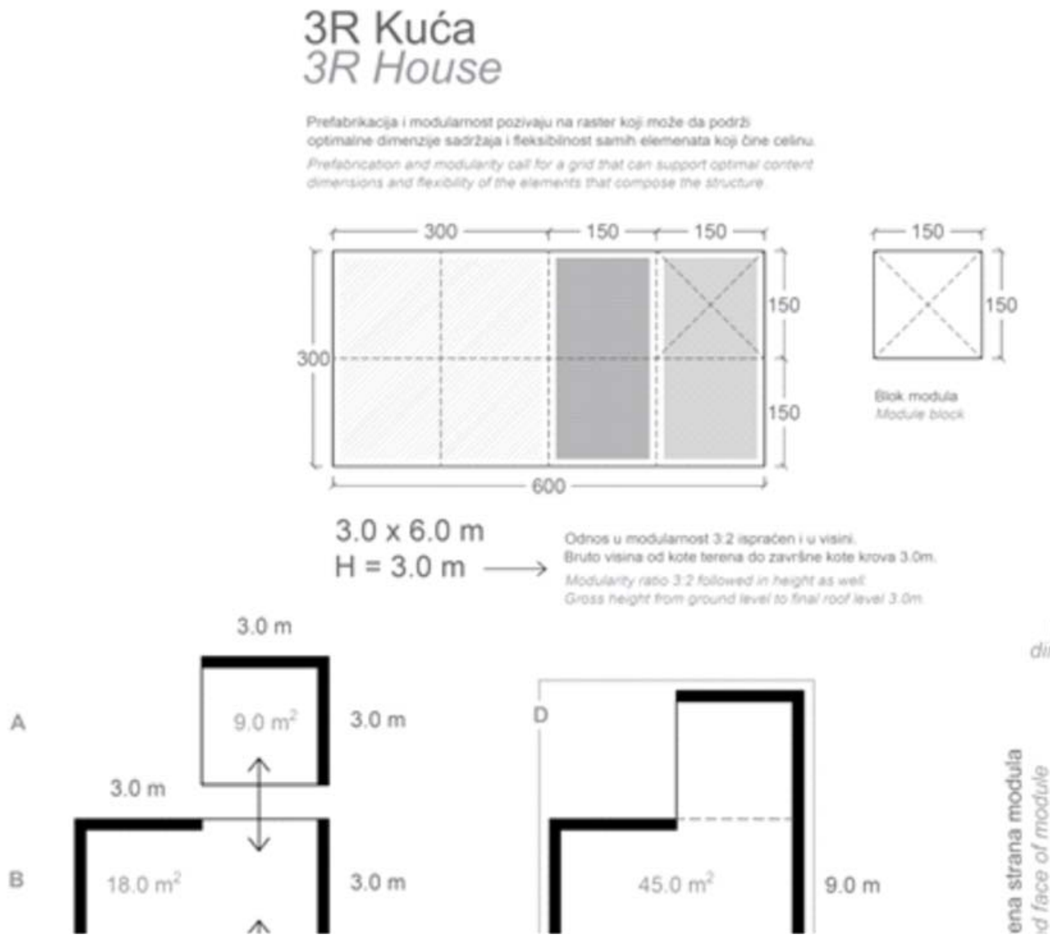


Figure 3.3-6 - Modularity of 3R Pilot house

Secondly, the functionally of 3R house was analysed. The house is planned as an Information pavilion during Circ-Boost implementation, and beyond project duration in an adequate location. Accordingly, it is designed as a space for presentations, meetings, exhibitions etc., with a space for info desk and a toilet (figure below).

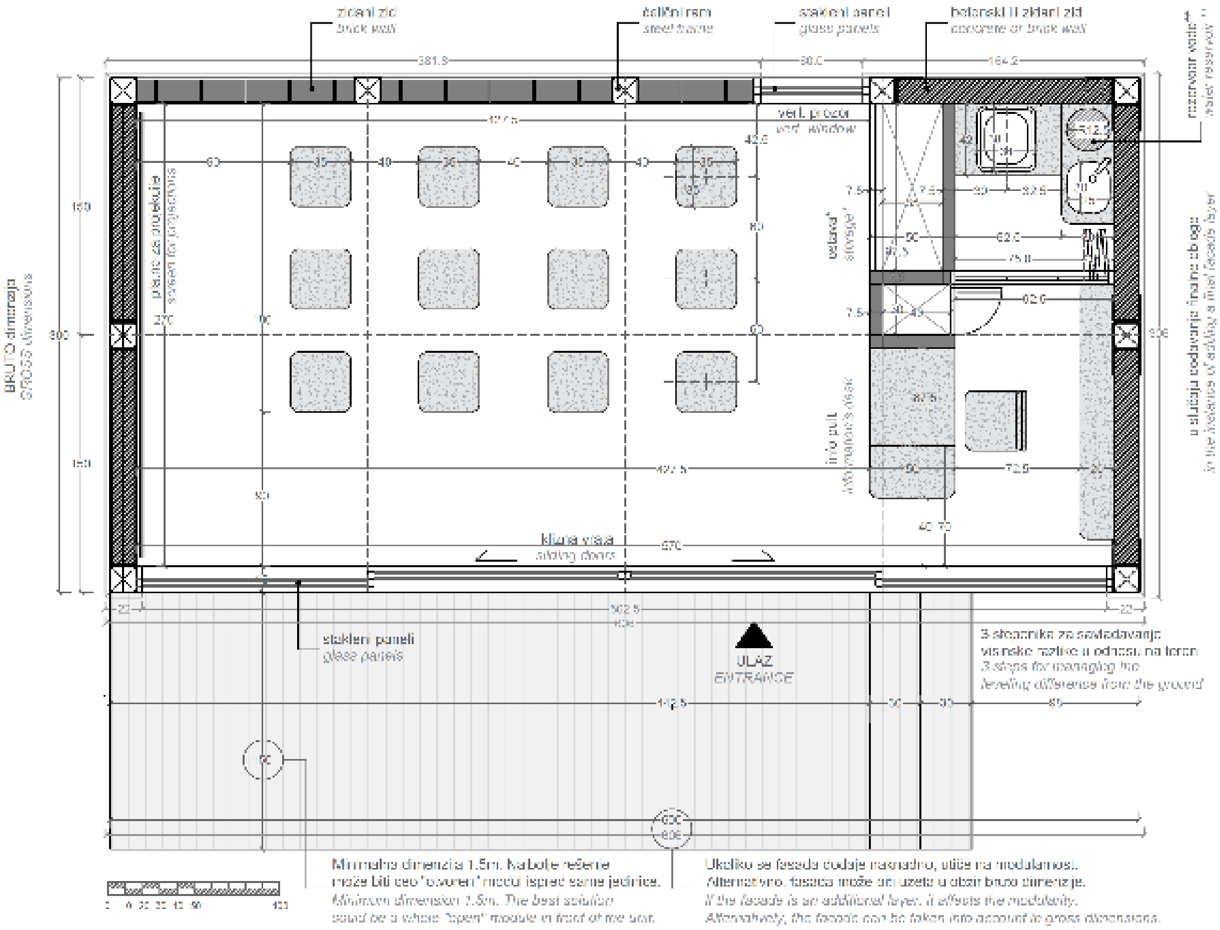


Figure 3.3-7 - Architectural conceptual layout of 3R Pilot house

Thirdly, the 3R Pilot house is designed to be sustainable not only for structural part of the house, but also for floor slab, façade and roof. Mood boards and ideas for façade and roof solution are shown below. The final solutions will be defined according to local availability. Architectural design will be updated with details after adoptions of all solutions for 3R Pilot house

Figure 3.3-8 – Development of the roof design

Figure 3.3-9 – An example of green roof application

Figure 3.3-10 - Locally available solutions for green roof

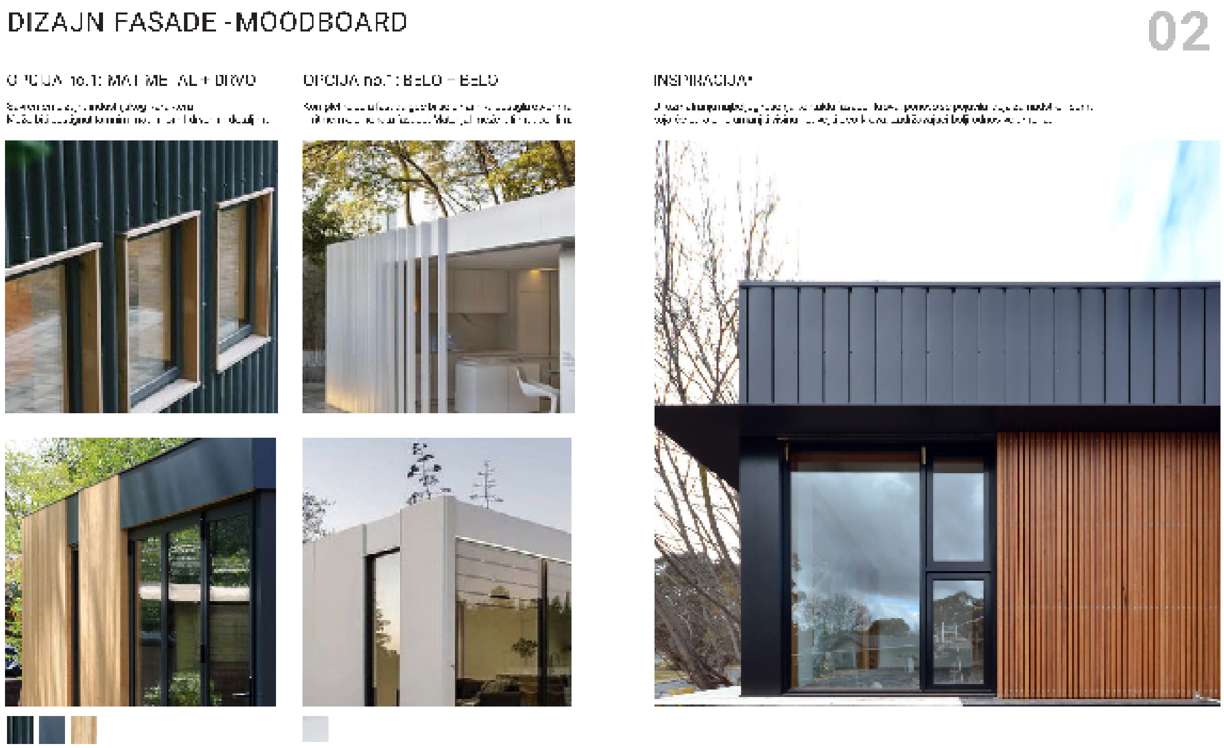


Figure 3.3-11 – Development of facade

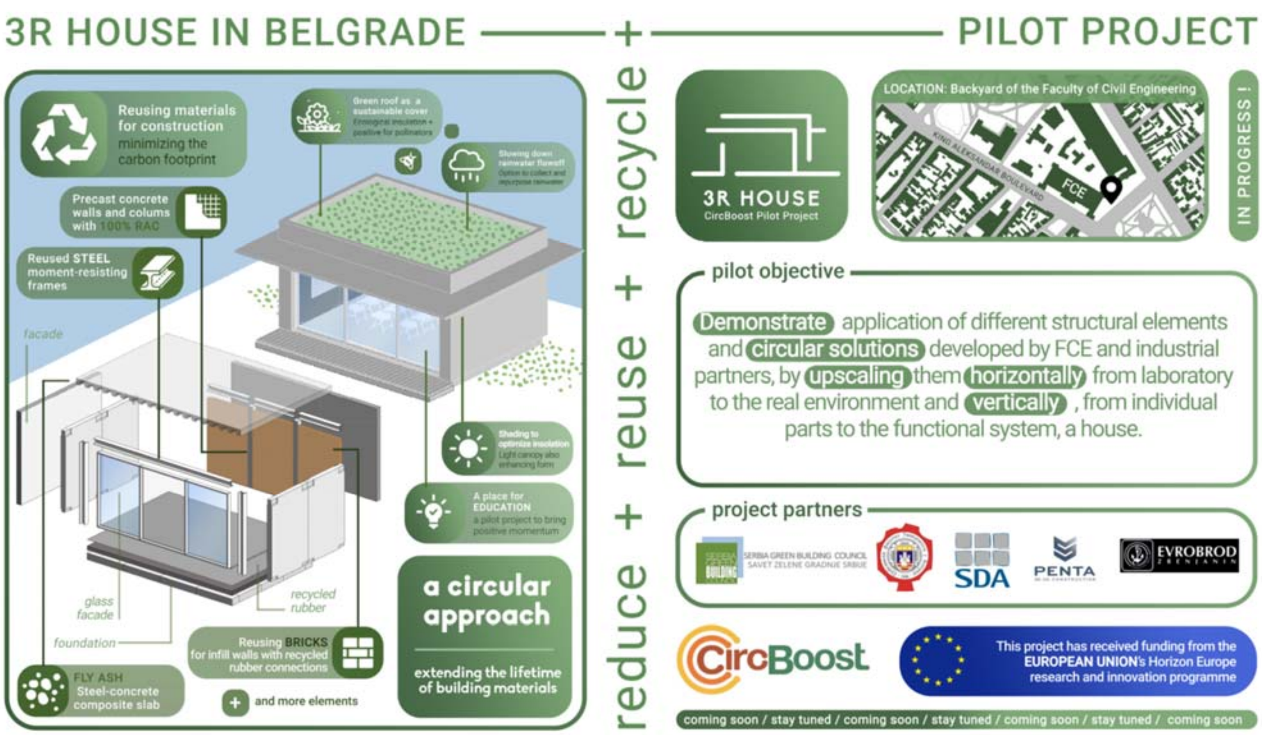


Figure 3.3-12 - Poster for promotional activities showing concept of 3R Pilot house

Conceptual structural design of the 3R Pilot house was done together with architectural design. All main structural elements were defined, with main connection concepts. The initial concept is shown below. The main structural elements of 3R Pilot house are: precast concrete columns and walls made with 100% of coarse recycled concrete aggregate, reused steel columns and beams, demountable composite slab made with steel sheeting and fly ash concrete. Reused bricks and rubber isolation are chosen for infill walls. All connections are demountable made with mechanical couplers and high-strength steel bolts. House front side will be made from steel frame and glass infill. The back façade will be made with steel frame and reused brick infill. Side facades will be made with precast concrete walls. Roof slab is a composite slab transferring load onto steel frames.

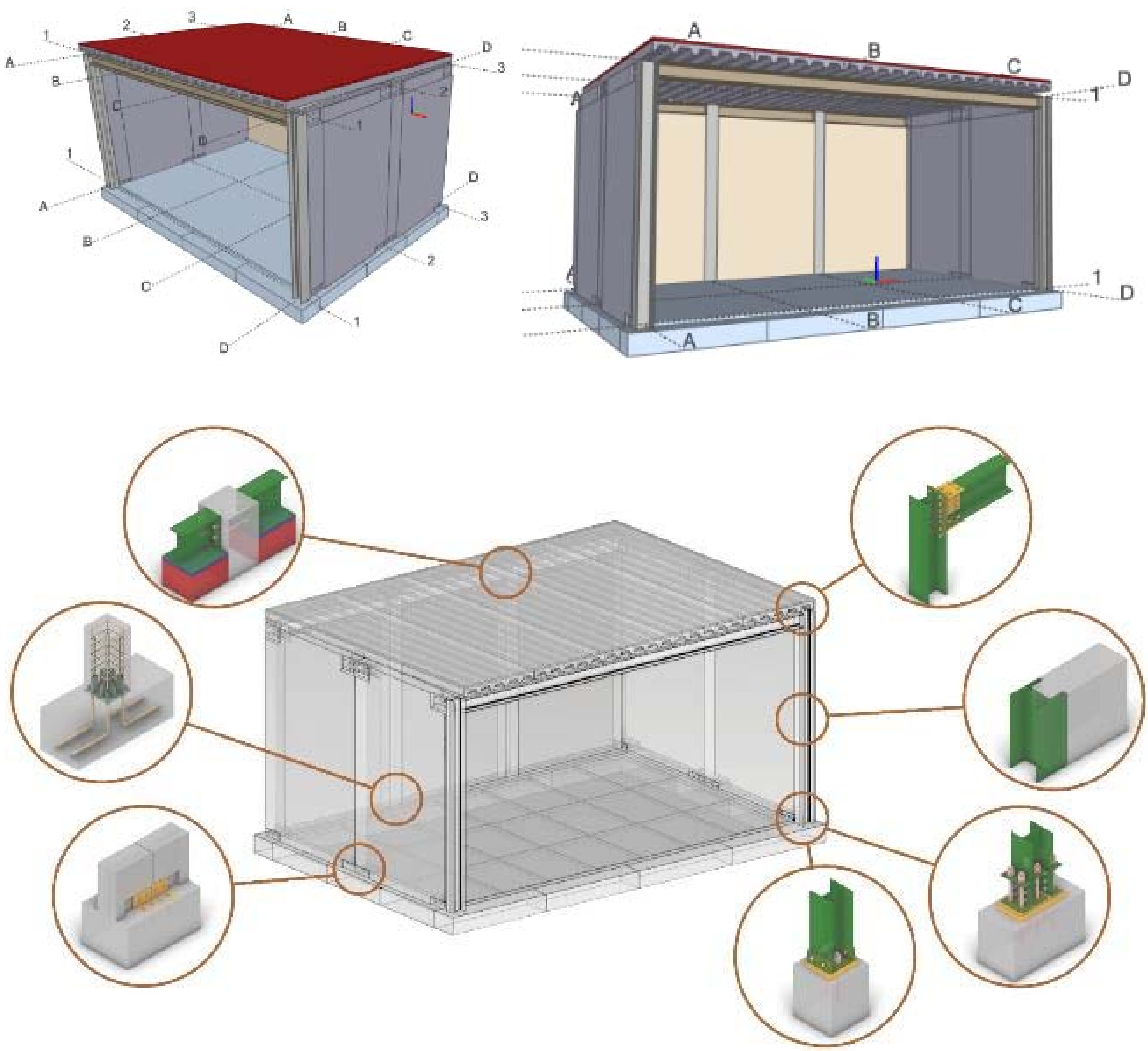


Figure 3.3-13 - 3R Pilot house with an initial concept for connections

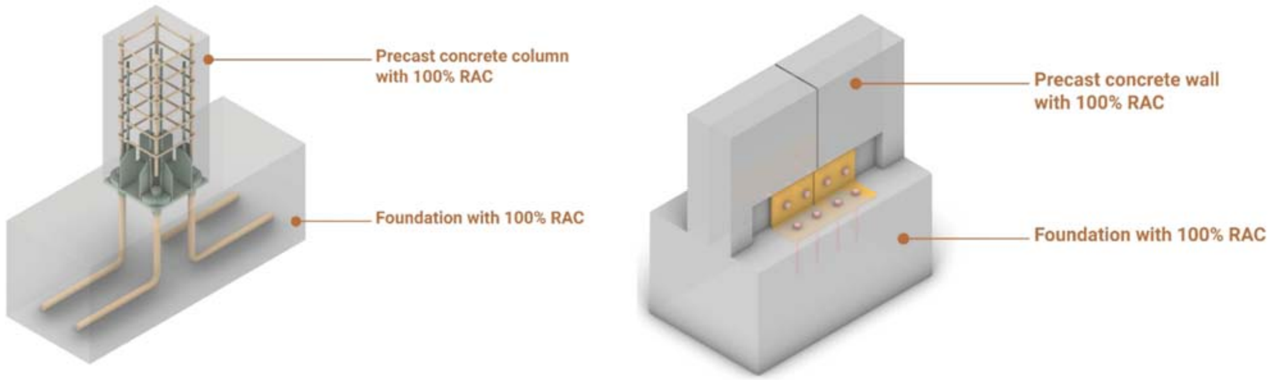


Figure 3.3-14 - Connection of precast concrete column and foundation (left), and precast concrete wall and foundation (right)

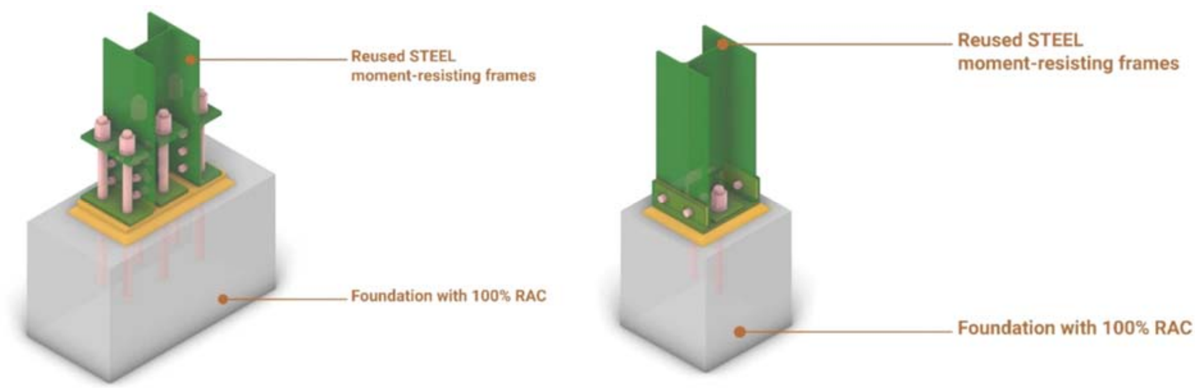


Figure 3.3-15 - Steel column and concrete foundation connections initial design

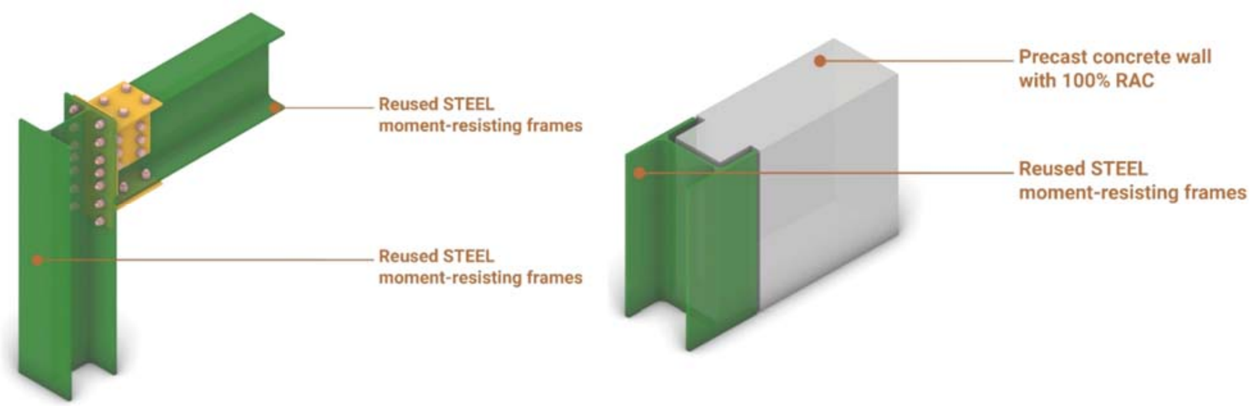


Figure 3.3-16 - Steel frame connection between column and beam (left) and initial detail of wall-steel column connection (right)

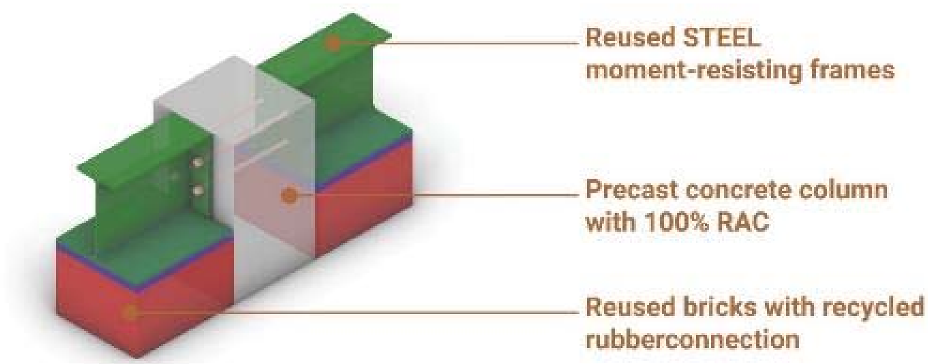


Figure 3.3-17 - Detail of concrete column-steel frame connection

T3.3. Detailed structural design together with partners (FCE, PENTA), M8-M28

Detailed structural design of 3R Pilot house was done regarding its global behaviour under relevant loads and analysing all structural elements. Three levels of seismic load were analysed:

1. Low, a_g=0.1g,
2. Medium, a_g=0.15g,
3. High, a_g=0.2g.

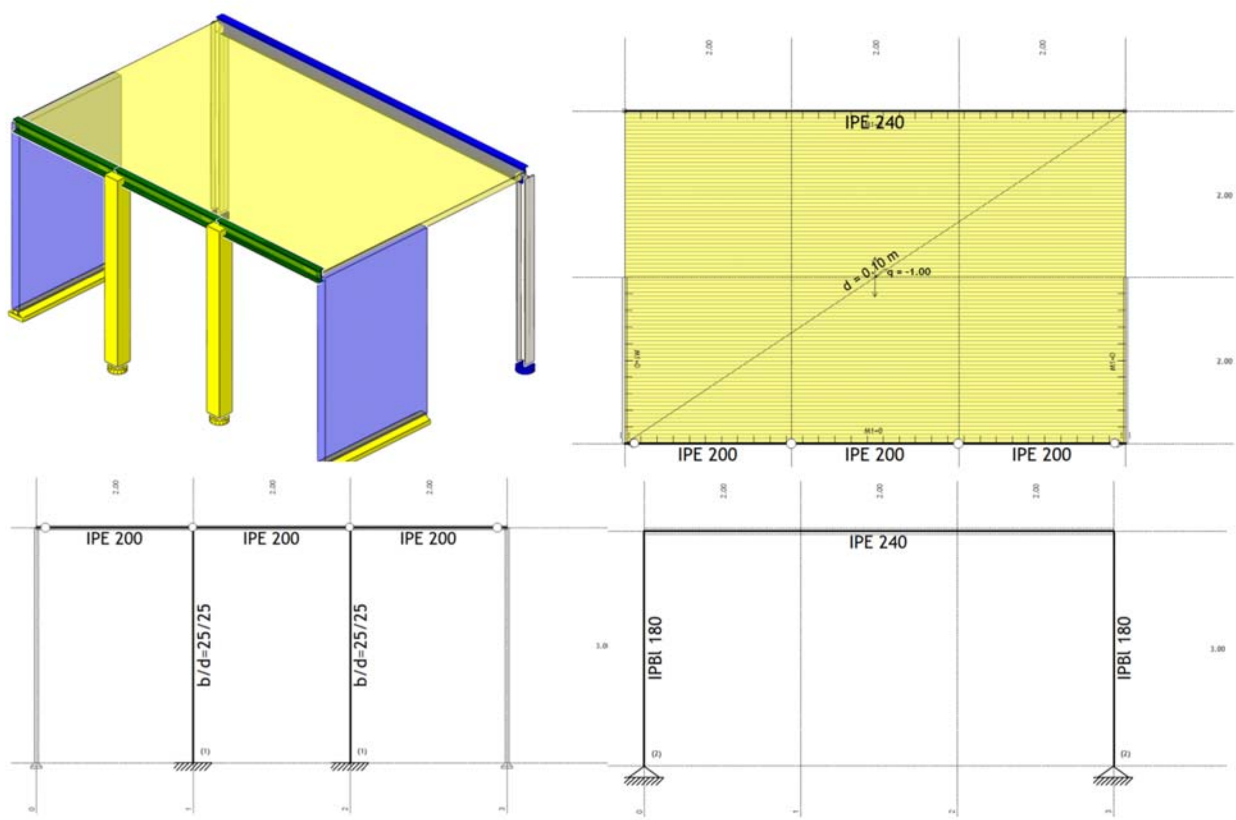


Figure 3.3-18 - Numerical structural model for 3R Pilot house

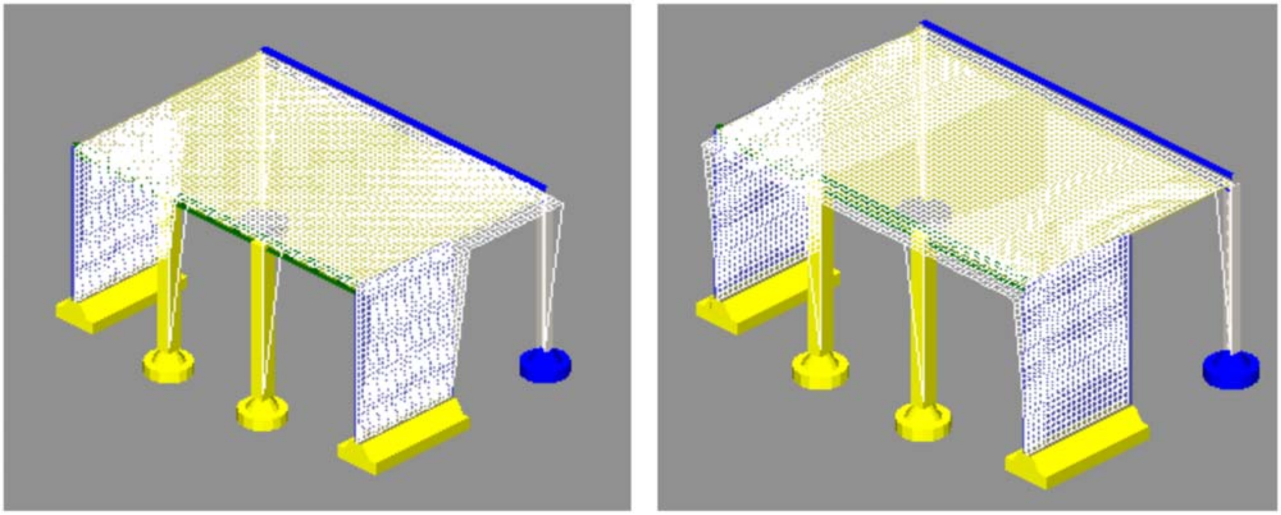


Figure 3.3-19 - 3R Pilot house modal response

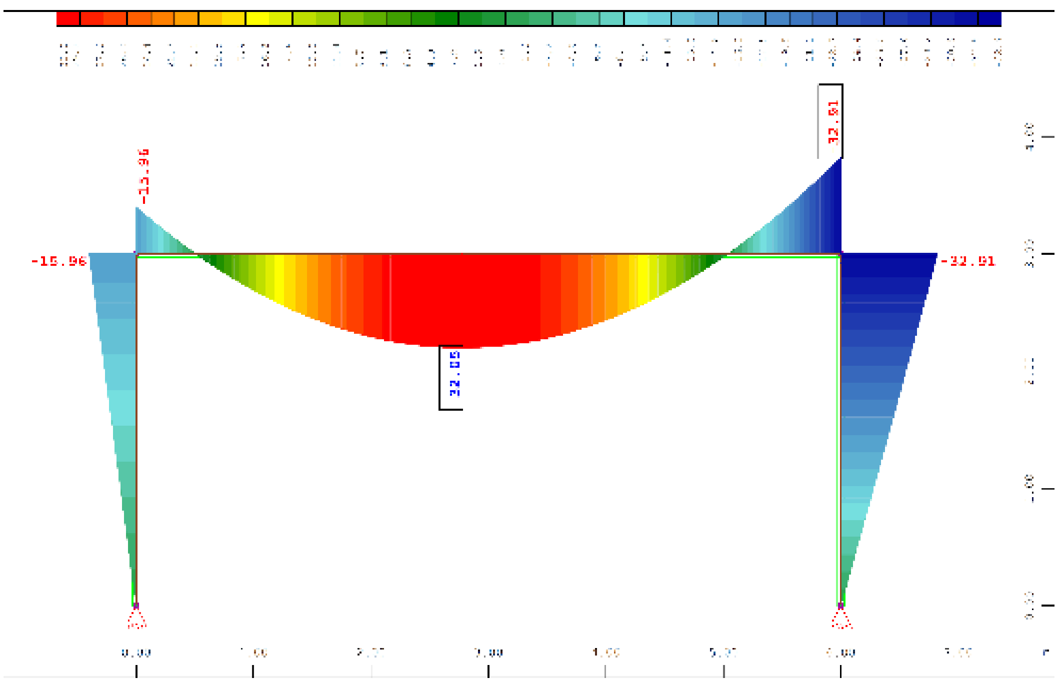


Figure 3.3-20 - Bending moment of steel frame

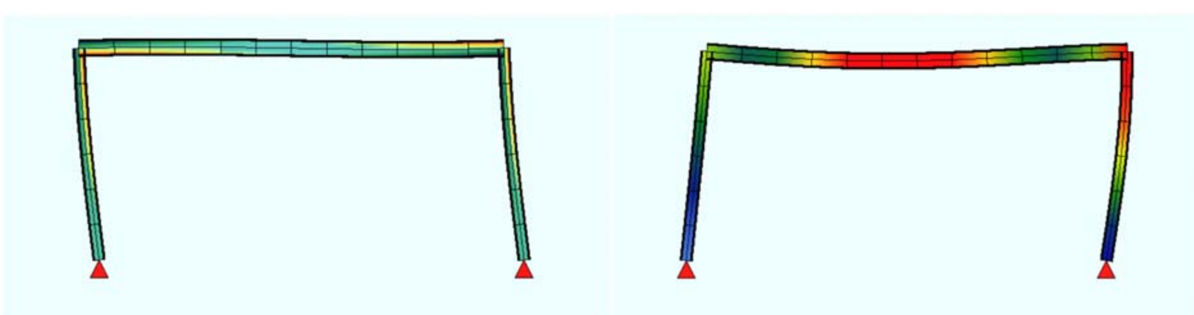


Figure 3.3-21 - Deformed shape of steel frame

T3.3.1. Design of concrete columns, walls and foundations for prototype testing (FCE, PENTA), M8-M20

Four different concepts for 3R Pilot house were analysed. Different concrete column dimensions and shapes were analysed, with different connections. This analysis was done together with PENTA.

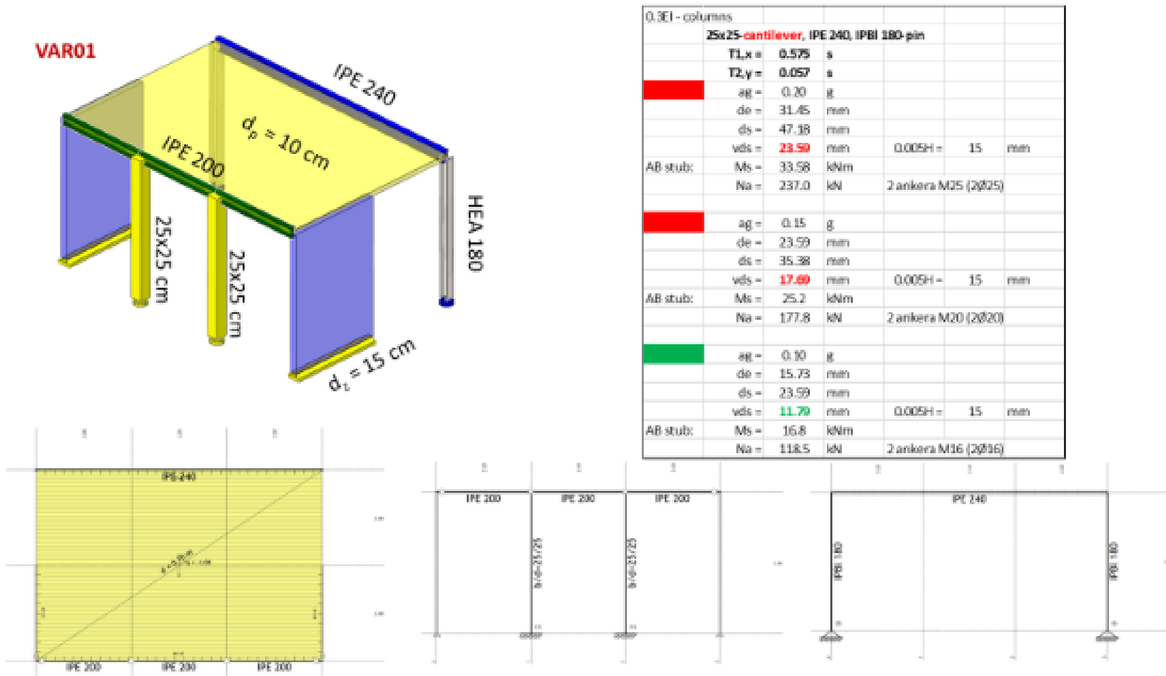


Figure 3.3-22 – Structural analysis of the pilot house – VAR 01

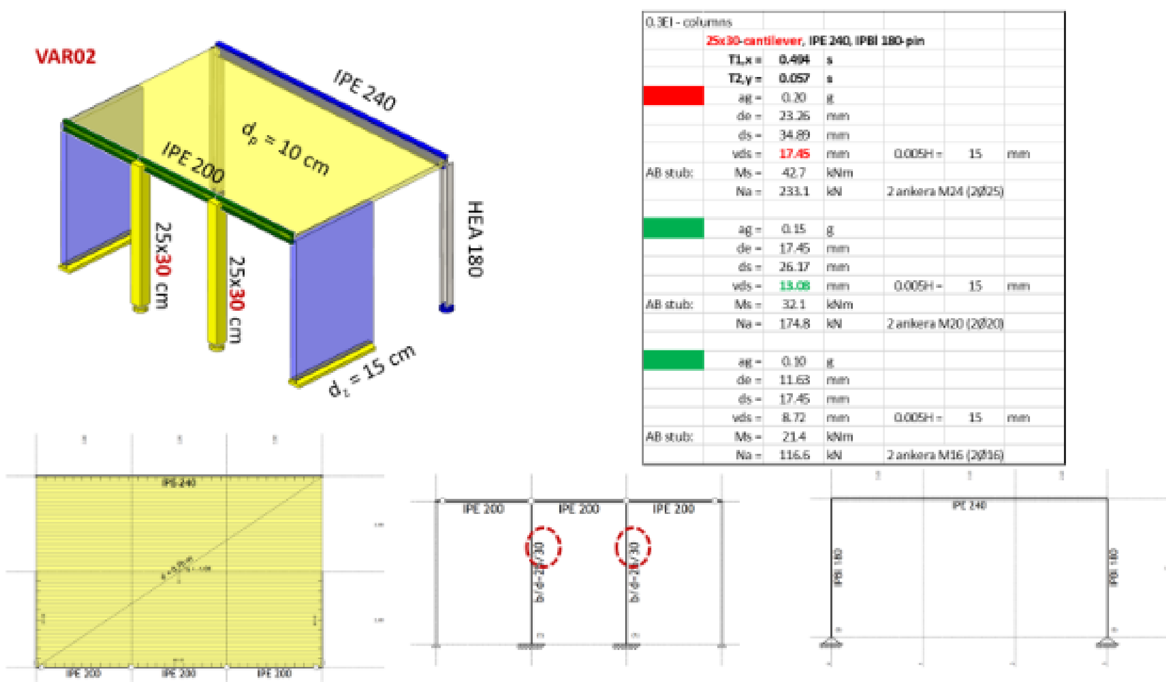
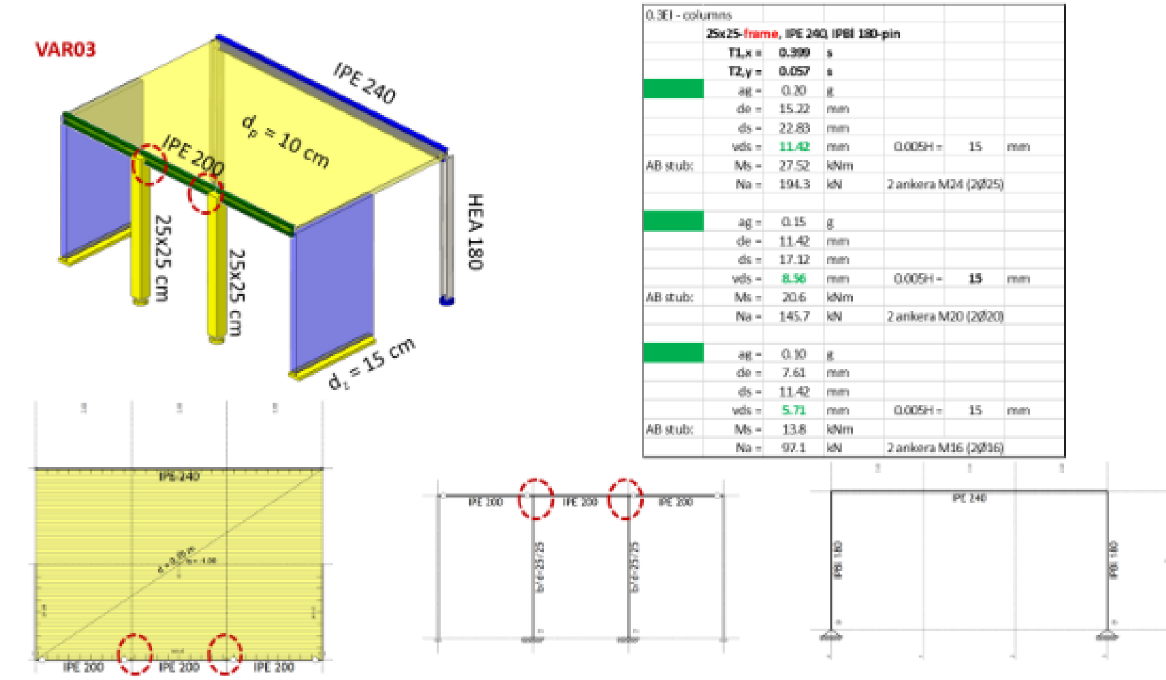
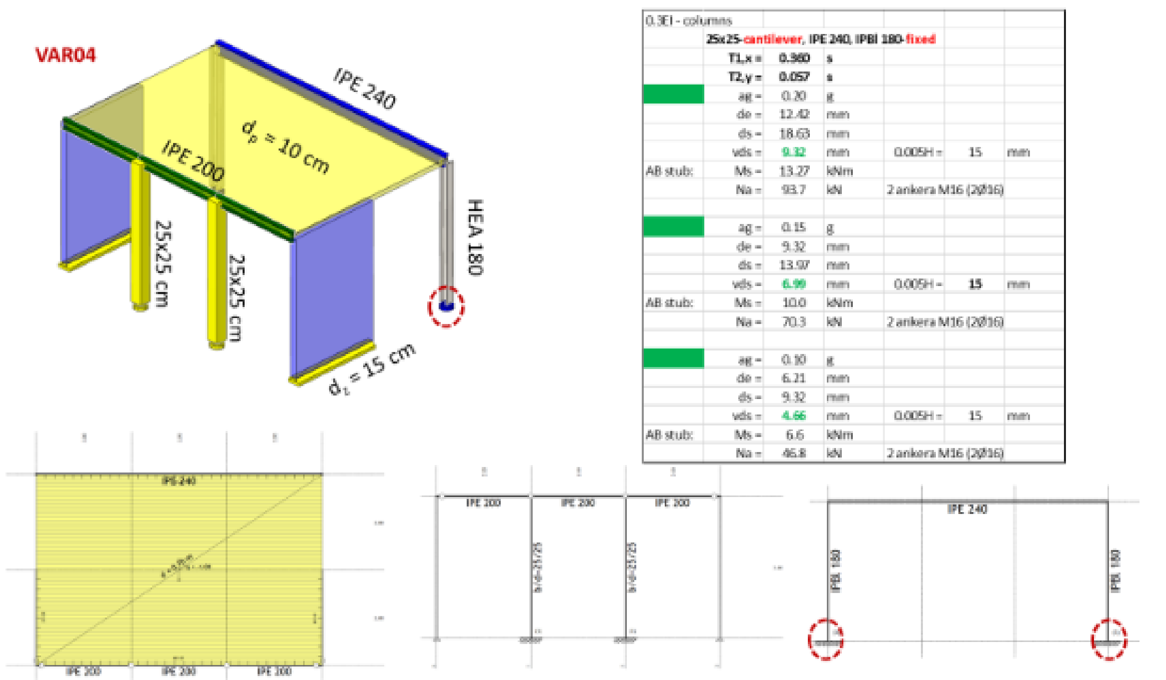


Figure 3.3-23 – Structural analysis of the pilot house – VAR 02



0.3EI - columns						
	25x25-frame, IPE 240, IPBI 180-pin					
	T1,x =	0.399	s			
	T2,y =	0.057	s			
	ag =	0.20	g			
	de =	15.22	mm			
	ds =	22.83	mm			
	vds =	11.42	mm	0.005H =	15	mm
AB stub:	Ms =	27.52	kNm			
	Na =	194.3	kN	2 ankera M24 (2Ø25)		
	ag =	0.15	g			
	de =	11.42	mm			
	ds =	17.12	mm			
	vds =	8.56	mm	0.005H =	15	mm
AB stub:	Ms =	20.6	kNm			
	Na =	145.7	kN	2 ankera M20 (2Ø20)		
	ag =	0.10	g			
	de =	7.61	mm			
	ds =	11.42	mm			
	vds =	5.71	mm	0.005H =	15	mm
AB stub:	Ms =	13.8	kNm			
	Na =	97.1	kN	2 ankera M16 (2Ø16)		

Figure 3.3-24 – Structural analysis of the pilot house – VAR 03



0.3EI - columns						
	25x25-cantilever, IPE 240, IPBI 180-fixed					
	T1,x =	0.380	s			
	T2,y =	0.057	s			
	ag =	0.20	g			
	de =	12.42	mm			
	ds =	18.63	mm			
	vds =	9.32	mm	0.005H =	15	mm
AB stub:	Ms =	13.27	kNm			
	Na =	93.7	kN	2 ankera M16 (2Ø16)		
	ag =	0.15	g			
	de =	9.32	mm			
	ds =	13.97	mm			
	vds =	6.99	mm	0.005H =	15	mm
AB stub:	Ms =	10.0	kNm			
	Na =	70.3	kN	2 ankera M16 (2Ø16)		
	ag =	0.10	g			
	de =	6.21	mm			
	ds =	9.32	mm			
	vds =	4.66	mm	0.005H =	15	mm
AB stub:	Ms =	6.6	kNm			
	Na =	46.8	kN	2 ankera M16 (2Ø16)		

Figure 3.3-25 – Structural analysis of the pilot house – VAR 04

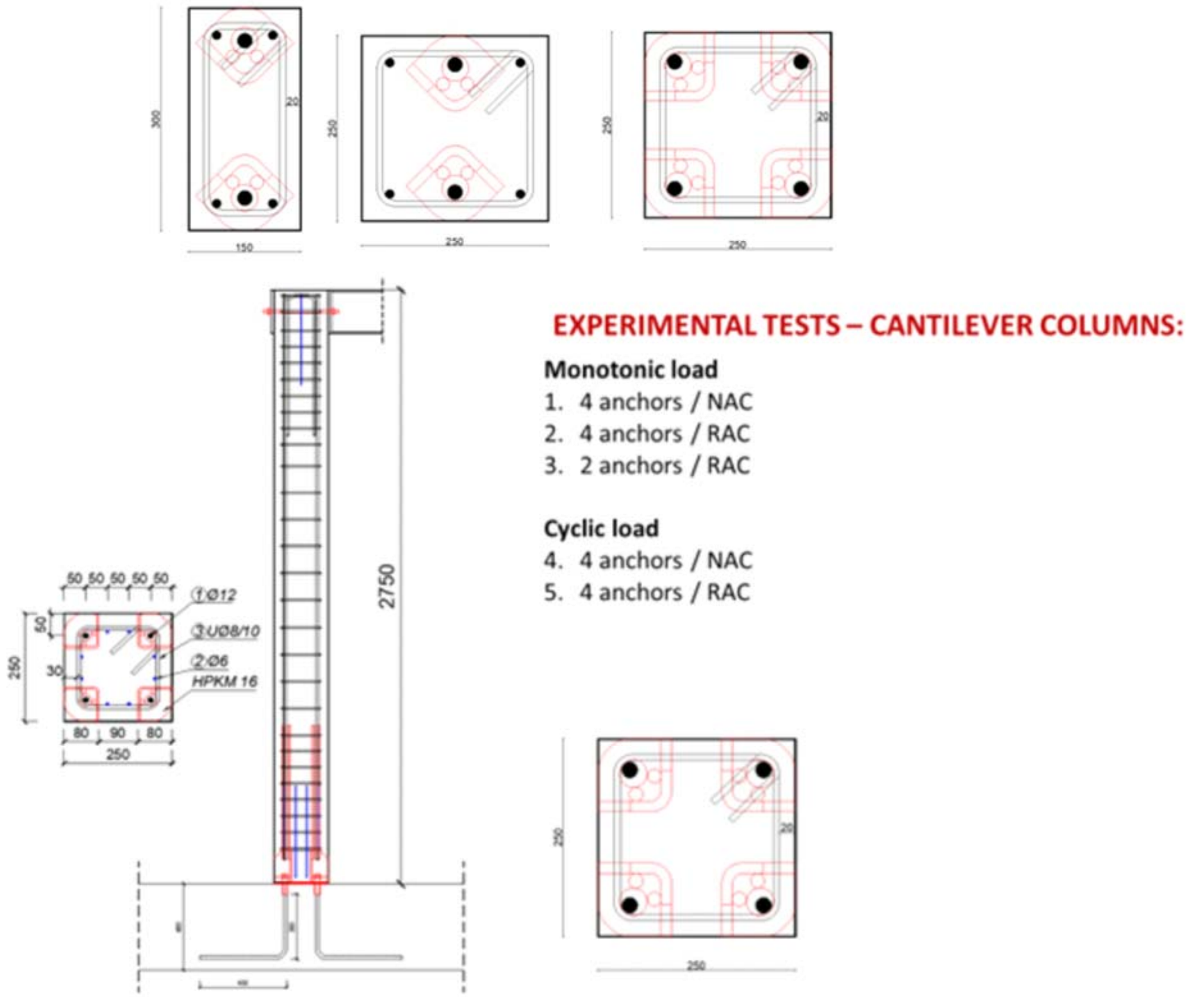


Figure 3.3-26 - Adopted concrete column design

EXPERIMENTAL TESTS – STEEL-CONCRETE FRAMES UNDER CYCLIC LOADS:

1. Bare frame: in-plane load
2. Frame with infill: in-plane load
3. Frame with infill: in-plane + out-of-plane loads

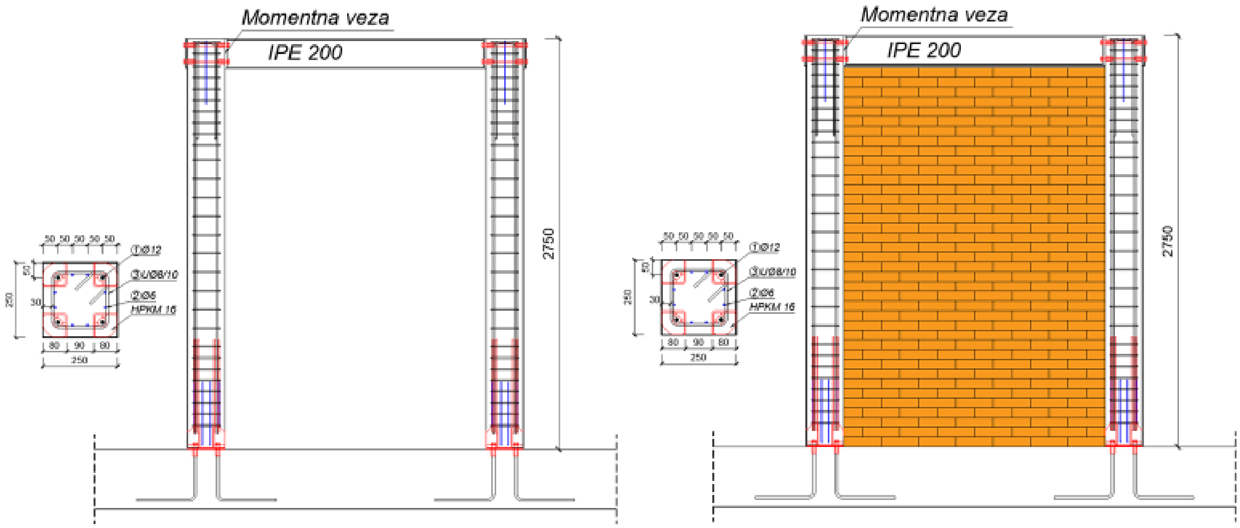


Figure 3.3-27 - Adopted concrete-steel frame design

T3.3.2. Design of composite slab (FCE, EBR), M8-M20

Composite slab preliminary design was done. The concept is shown below.

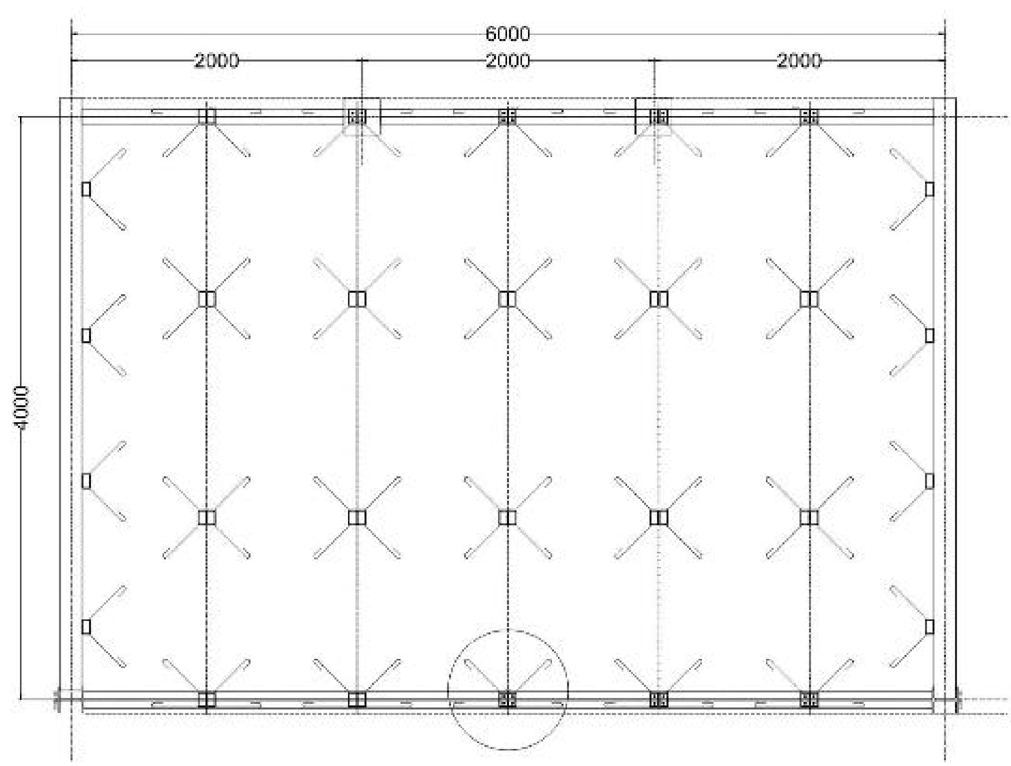


Figure 3.3-28 - Conceptual design of composite slab

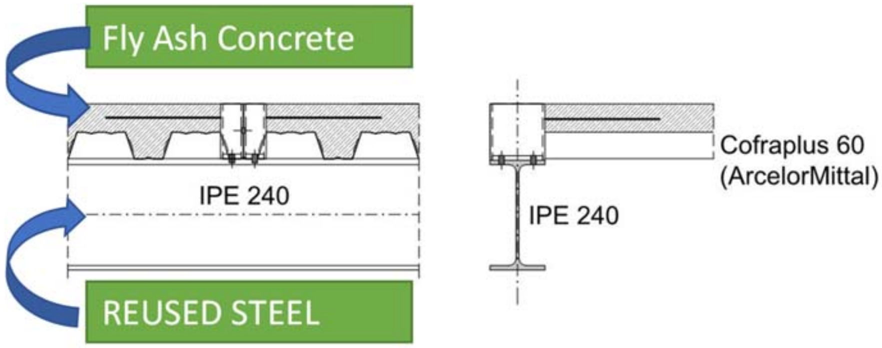


Figure 3.3-29 - Conceptual design of composite slab

T3.3.3. Design of rubber connection for infill walls for prototype testing (FCE, SDA), M17-M18

Together with SDA, conceptual structural design of brick infill walls with recycled rubber strip connection was done and afterwards based on the numerical model exact dimension and amount of rubber strips was defined. The drawings of the details of the connection were made.

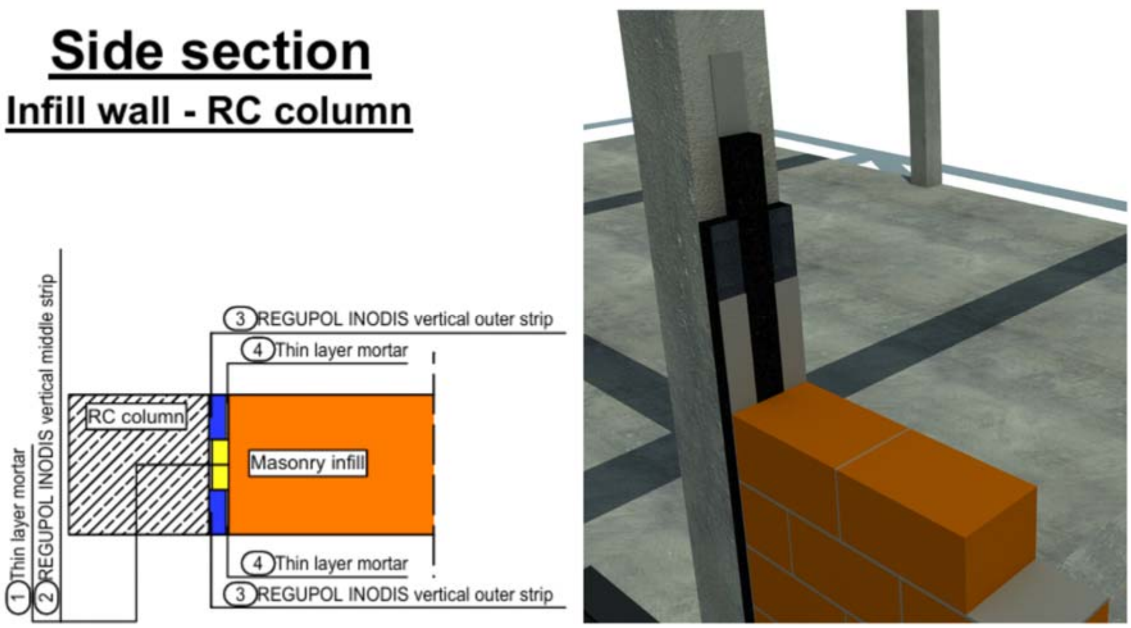


Figure 3.3-30 - Brick infill walls with recycled rubber strip connection

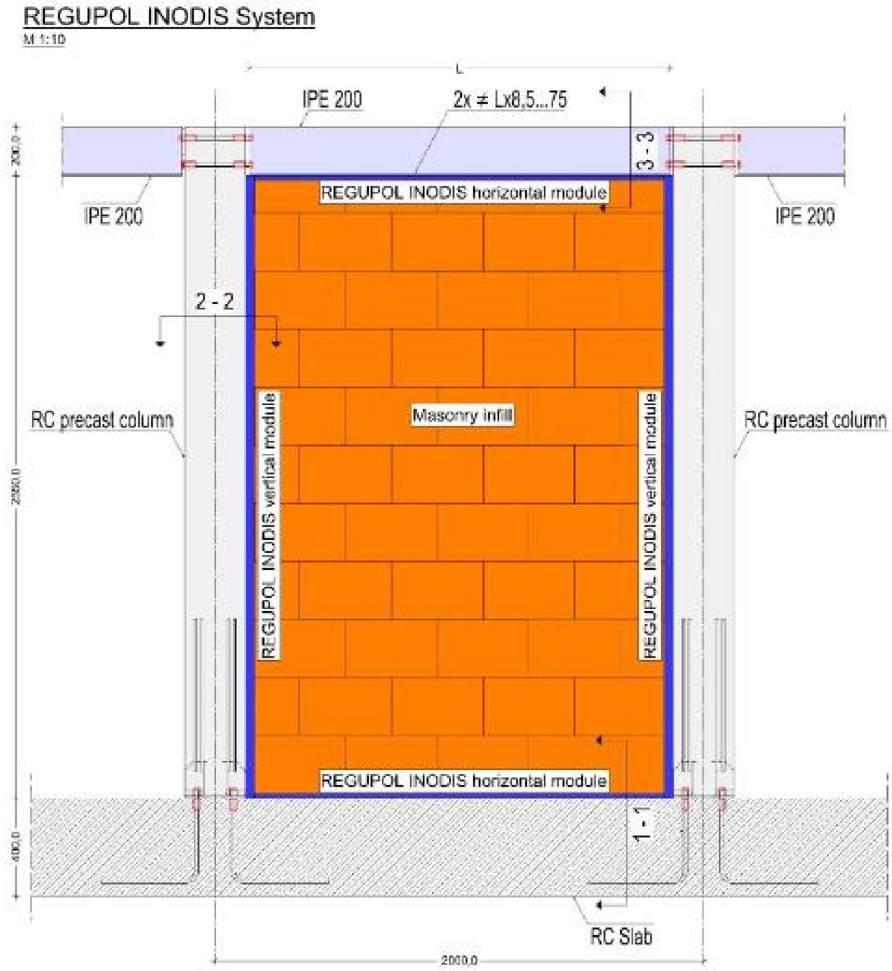


Figure 3.3-31 - Adopted concrete-steel frame with infill and INODIS design

Design of INODIS rubber thickness:

VERIFICATION OF TRANSFERRED SHEAR FORCE

Table-1: In-plane design resistance in shear $V_{ap,Rd}$

Infill	Infill panel height h_{ap} [m]	Infill panel length l_{ap} [m]	Thickness t_{ap} [m]	Length of diagonal l_s [m]	f_{vk0} [kPa]	$V_{ap,Rd}$ [kN]
W1	2.5	1.68	0.25	3.01	200	84.00
W2	2.5	1.68	0.25	3.01	200	84.00
W3	2.5	1.68	0.25	3.01	200	84.00

					0,1g								
Infill	α [°]	l_{cs} [m]	$γ_{r,SD}$ [-]	30% of $V_{ap,Rd}$ [kN]	$d_{s,max}$ [mm]	$d_{s,SD}$ [mm]	Strain [-]	Regupol Inodis vertical	Thickness of Inodis [mm]	$σ_{max}$ [N/mm²]	$σ_{sj,D}$ [N/mm²]	$V_{c,ap}$ [kN]	Verification
W1	56.10	1.350	1.1	25.20	16.39	9.0145	0.300	Plus	30	0.107	0.0535	18.06	PASS
W2	56.10	1.350	1.1	25.20	16.39	9.0145	0.300	Plus	30	0.107	0.0535	18.06	PASS
W3	56.10	1.350	1.1	25.20	16.39	9.0145	0.300	Plus	30	0.107	0.0535	18.06	PASS

T3.3.4. Design of demountable joints for prototype testing (FCE), M14-M17

Two demountable joints of the pilot house portal frame have been selected for prototype testing: 1) a beam-to-column steel joint and 2) a steel-to-concrete column base joint that utilizes demountable anchor bolts. The portal frame, comprising the beam and columns, is constructed from reclaimed hot-rolled IPE and HEA sections sourced from steel intended for recycling. The joints incorporate integral steel link, Tee-flange (or UPE-flange) components, as well as angle-web components, all of which are fabricated from new steel. Structural units are interconnected with M12 and M16 bolts, grade 10.9, and no welding is used in the assembly.

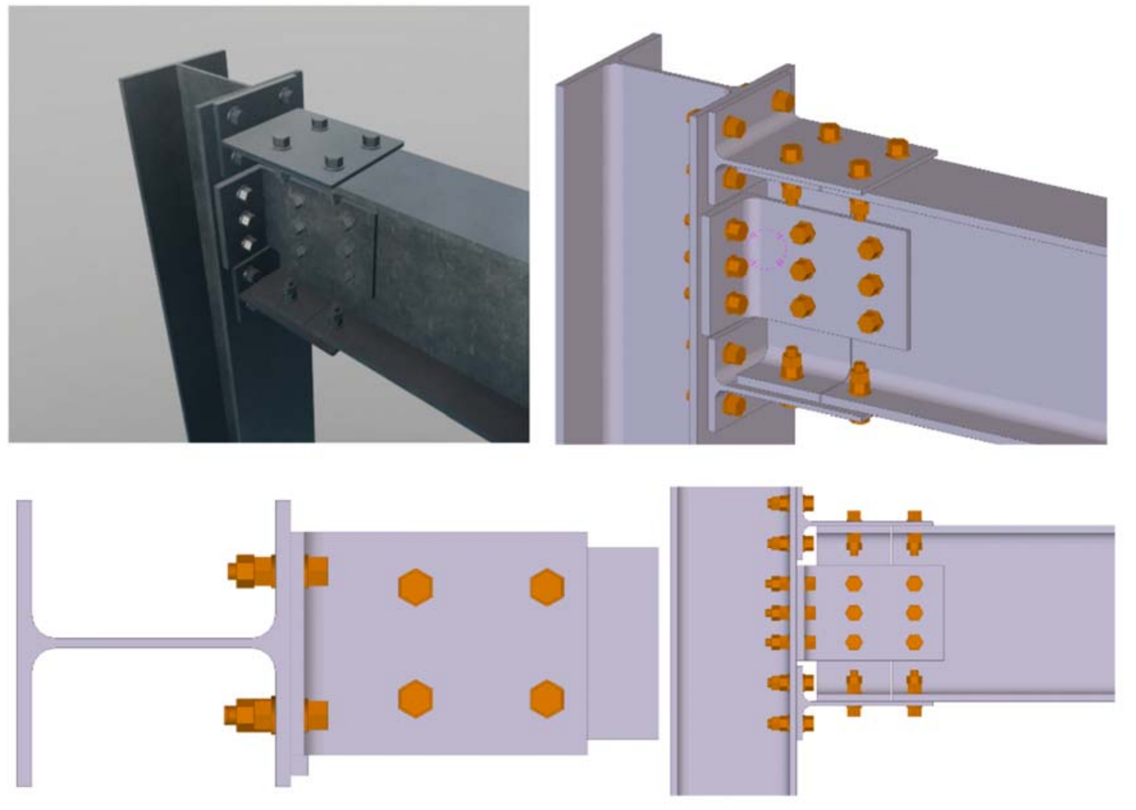


Figure 3.3-32 - Moment resisting beam-to-column steel joint

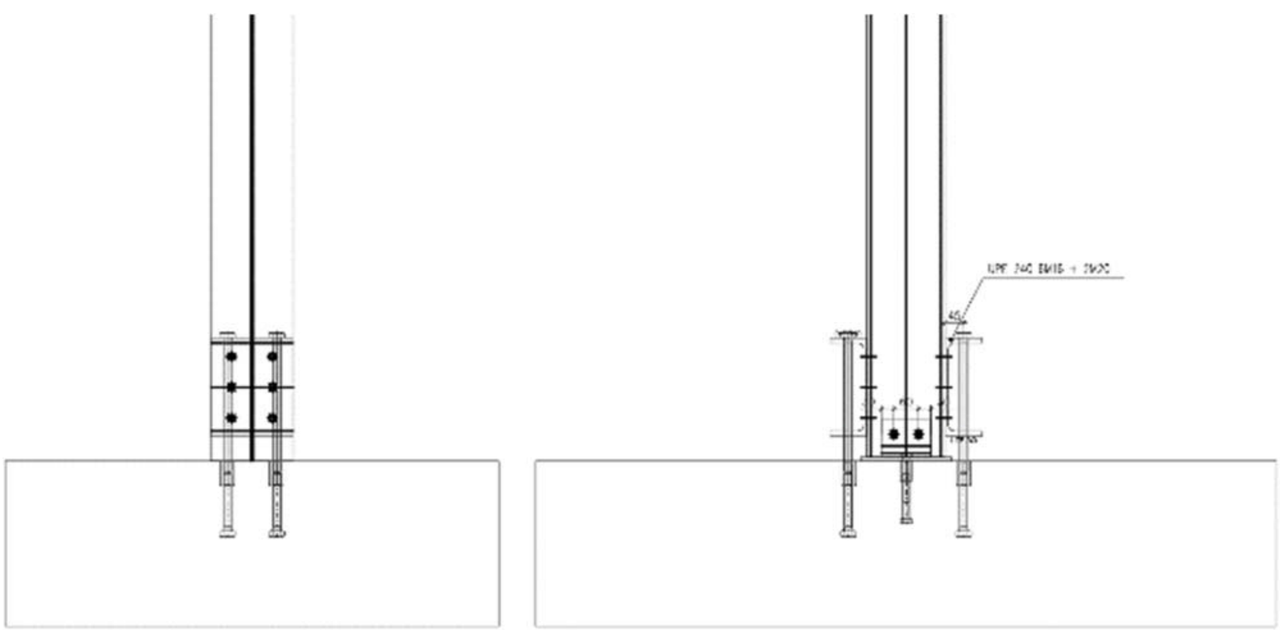


Figure 3.3-33 - Steel-to-concrete column base joint

T3.4. Database of potential sources of recycled and reusable materials (FCE), M9-M18

After market survey, a database of potential reused and recycled materials that are available in Serbia was made. Companies whose business is related to recycled concrete aggregate, reused steel and brick or fly ash are identified. After initial meetings with the representatives of those companies, a list with relevant contacts and data was created. This list will be updated during CircBoost implementation, and presented to public together with pilot house.

There are three possible sources of recycled concrete aggregate (RCA) in Serbia:

1. Construction and Demolition Waste Treatment Facility,
2. Demolition companies,
3. Precast concrete companies.

The only one that has commercially available RCA is one construction and Demolition Waste Treatment Facility in Vinča, Belgrade that is being operated by Beo čista energija. Aggregate obtained from Beo čista energija plant is crushed concrete without reinforcement, and it needs sieving to be suitable for the use in concrete. Demolition companies don't have available quantities of RCA at all times (Šuša company, figure below). They are highly influenced by the demolition industry. Precast concrete factories usually have high grade concrete waste, as a waste from their production. It is pure concrete waste, but those companies still don't have adequate crushers for commercial production of RCA. However, they expressed an interest in obtaining them if need for RCA increases in Serbian market.

Figure 3.3-34 - Šuša Company, Novi Sad-Recycled concrete aggregate and jaw crusher

Up to 2024, fly ash was only available in thermal power plants. Commercially available fly ash was accessible for silos, but it is very coarse. The use of fly ash in concrete is defined with SRPS EN 450: Fly ash for concrete standard, and fly ash from silos does not meet the requirements without mechanical and/or chemical treatment. From 2025, standardized fly ash will be commercially available in Tekon fly ash company. Reused steel in available in Serbia in many steel structure companies, which after disassembling of the existing steel buildings, collect steel for reuse and recycling. This steel can be purchased for around 0.20 EUR per kilo. Reused/old brick can be found in Serbian market. Two companies that produce now, but also offer treatment and cleaning of old bricks and tiles. Regarding the recycled rubber, in Serbia it was not possible to find the producers for recycled rubber strip connection. There are couple of companies doing rubber recycling, but mostly just shredding the old tyres and not producing any product such as recycled rubber strips that could be used for the purpose of infill wall connection.

No	Company na	Company activities	Web site	Location	Process	Type of mate	Material specification and commercial availability
1	Beo čista energija	Part of The Belgrade Waste Management PPP Project. Beo čista energija is organizing the Construction and Demolition Waste (CDW) Treatment Facility which is in operation from August 2021 and includes a crusher for inert CDW targeting recovery of CDW and a temporary storage of recovered inert CDW (pending and subject to any off take) for recycling activity of such construction & demolition waste. The process consists of: reception of construction and demolition waste, basic sorting of construction and demolition waste, crushing and screening of inert waste into different size ranges, to produce: granulates, material for road sublayers (unbound base courses), backfill materials, etc.	https://www.bcenergy.rs/rs/	Vinča, Belgrade, Serbia	Recycling	Recycled concrete aggregate	Construction and Demolition Waste Treatment Facility capacity is 200,000 tons/year of CDW. Available quantities are not constant, they are influenced by the construction and demolition industry. Crushed concrete waste can be purchased for the following prices: fraction 0/32 0.5 €/t, 32/80 3 €/t, 80/150 5 €/t. Beo čista energija does not provide finer grading, so for common concrete aggregate fractions (0/4, 4/8, 8/16, 16/32) additional crushing/sieving is necessary. Quality of available crushed concrete varies according to source. In two different locations when crushed concrete was obtained for Pilot 3 house, aggregate water absorption was significantly different (avg. 6.7% and 3.7%).
2	Šuša company	Demolition and recycling of construction waste in two steps: classification of material by its composition and cutting of rebars and crushing of concrete, stone and other solid materials. After crushing, the materials (concrete, stone ...) are graded by size and transported to their own construction sites or delivered to customers.	http://www.susa.rs/index.php/e	Novi Sad, Serbia	Recycling	Recycled concrete aggregate	There are no available quantities of recycled concrete aggregate at all times. They are highly influenced by the demolition industry. Commercially available recycled concrete aggregate is not available at the moment.
3	Elita Cop	Demolition company that has a mobile crushing plant where the demolished parts of the structure are separated into steel and crushed concrete, which is further used in the construction of access roads.	https://www.elitacop.com/	Belgrade, Serbia	Recycling	Recycled concrete aggregate	There are no available quantities of recycled concrete aggregate at all times. They are highly influenced by the demolition industry. Commercially available recycled concrete aggregate is not available at the moment.
4	Put Inženjering	Design and construction of cast in situ and precast concrete elements and buildings, concrete factory, querry and plant for recycling fresh concrete.	https://putinzenjering.com/	Niš, Nova Pazova, Serbia	Recycling	Recycled concrete aggregate	Put Inženjering offers the treatment of constructional non-hazardous waste by mechanical crushing, and classification of aggregates into three types of fractions: 0 – 15mm, 5 – 45mm, 45 – 160mm.
5	Thermal Power Plant Nikola Tesla B	Thermal power plant Nikola Tesla B is one of 8 serbian thermal power plants, providing more than 70% of electricity in Serbia. As a result, more than 7 million tones of fly ash is being produced each year and deposited onto landfields.	https://www.eps.rs/cir/tent/Documents/PUBLIKACIJE/Termoelektrana%20Nikola%20Tesla%20B.pdf	Obranovac, Serbia	Use of waste materials	Fly ash	Fly ash is being deposited onto landfills or in silos. It is commercially available in bulk. The price is a couple of euros per ton. Fly ash obtained in this way is very coarse, and needs to be treated (mechanically and/or chemically) to be suitable for use in concrete. Low uniformity and heterogeneity are also an issue.
6	Lafarge	Lafarge is a worldwide cement producer, with a cement factory also in Serbia.	https://www.lafarge.rs/	Beočin, Serbia	Use of waste materials	Fly ash	Lafarge is planning to open a fly ash plant in 2027. Currently, only blended cements with up to 50% of fly ash, granulated blast furnace slag and limestone can be purchased.
7	Tekon	Tekon is a design and consulting company that provides services in the following fields: Mineral exploration, Promotion and implementation of management systems, Environment protection, Energy, Privatization process.	https://www.tekon.rs/	Paraćin, Srbia	Use of waste materials	Fly ash	In 2025, a fly ash plant will start with its production. Fly ash for Serbian thermal power plants standardized according to SRPS EN 450 will be commercially available.
8	Baumit	Production of construction materials, primarily focusing on building and renovation products.	https://baumit.rs/	Aranđelovac, Serbia	Reuse of steel structure	Steel	As the factory owner, they dismantled the existing building facility in Celje, Slovenia. Then, they reassembled the same structure in Arandjelovac, Serbia. Due to the modernization and equipment upgrading, some structural elements were not used and they were replaced with new ones. These steel structure elements were collected.
9	Iva procesna oprema	Manufacturing of the process equipment.	https://www.ivaprocesnaoprema	Aranđelovac, Serbia	Reuse of steel structure	Steel	They make processing equipment. They gather used steel structural pieces while reconstructing various types of platforms and equipment support structures.
10	GRAPPS	Development and installation of steel structures, industrial plant maintenance, project management and engineering.	https://grapps.net/en/home/	Smederevo, Serbia	Reuse of steel structure	Steel	The manufacturing steel structure company, which after disassembling of the existing steel buildings, collects steel for reuse and recycling.
11	Montimpex	Metalurgy product manufacturing and trading, metal recycling, and secondary raw material procurement.	https://montimpex.rs/	Smederevo, Serbia	Recycling, Re	Steel	Montimpex is a dealer of reused steel elements. The manufacturing steel companies sell steel elements to Montimpex after structure disassembling. Montimpex also collects steel for recycling.
12	Dekorativna cigla	Producing and selling different types of bricks and tiles.	https://www.dekorativnaciglaba	Novo Selo, Serbia	Reuse	Clay bricks and tiles	Company offers treatment and cleaning of old bricks and tiles. But also production of new clay bricks and tiles.
13	APA dekor cigla	Producing and selling different types of bricks and tiles.	https://www.secenacigla.rs/	Apatin, Serbia	Reuse	Clay bricks and tiles	Company offers treatment and cleaning of old bricks and tiles. But also production of new clay bricks and tiles.

T3.5 Material procurement and concrete design (FCE), M6-M25

T3.5.1. Recycled concrete aggregate-RCA, M6-M13

Recycled concrete aggregate was obtained from Beo čista energija, and additionally sieved into two size fractions, 4-8mm and 8-16mm. Aggregate was than stored in PENTA concrete plant for future concrete production, and a part was transported to FCE for material testing.

Figure 3.3-35 - Beo čista energija – recycled concrete aggregate

T3.5.3. Old/used bricks, M10-M19

Investigation of the market in Serbia was done regarding the potential of reuse of the old bricks. Since there are a lot of old masonry buildings, there is big potential for reusing bricks. It is mostly solid brick, which is even easier for cleaning and preparing for the reuse. There is availability of different sizes but usually 25cm and 30cm long bricks. Most of the old bricks were collected by the private home owners that were demolishing their old houses. There is no organized old brick collection, only a few small companies doing it. Probable reason is the lack of awareness and potential. 5000 old bricks with the size 6.5cm x 12cm x 25cm was procured and stocked, ready for the use for the purposes of the Pilot 3 house. Regarding the recycled rubber strip connection, in Serbia it was not possible to find the producers. There are couple of companies doing the rubber recycling, but mostly just shredding the old tyres and not producing any product such as recycled rubber strips that could be used for the purpose of infill wall connection. Therefore, REGUPOL company will donate needed amounts of the recycled rubber strips.

Figure 3.3-36 - Reused bricks

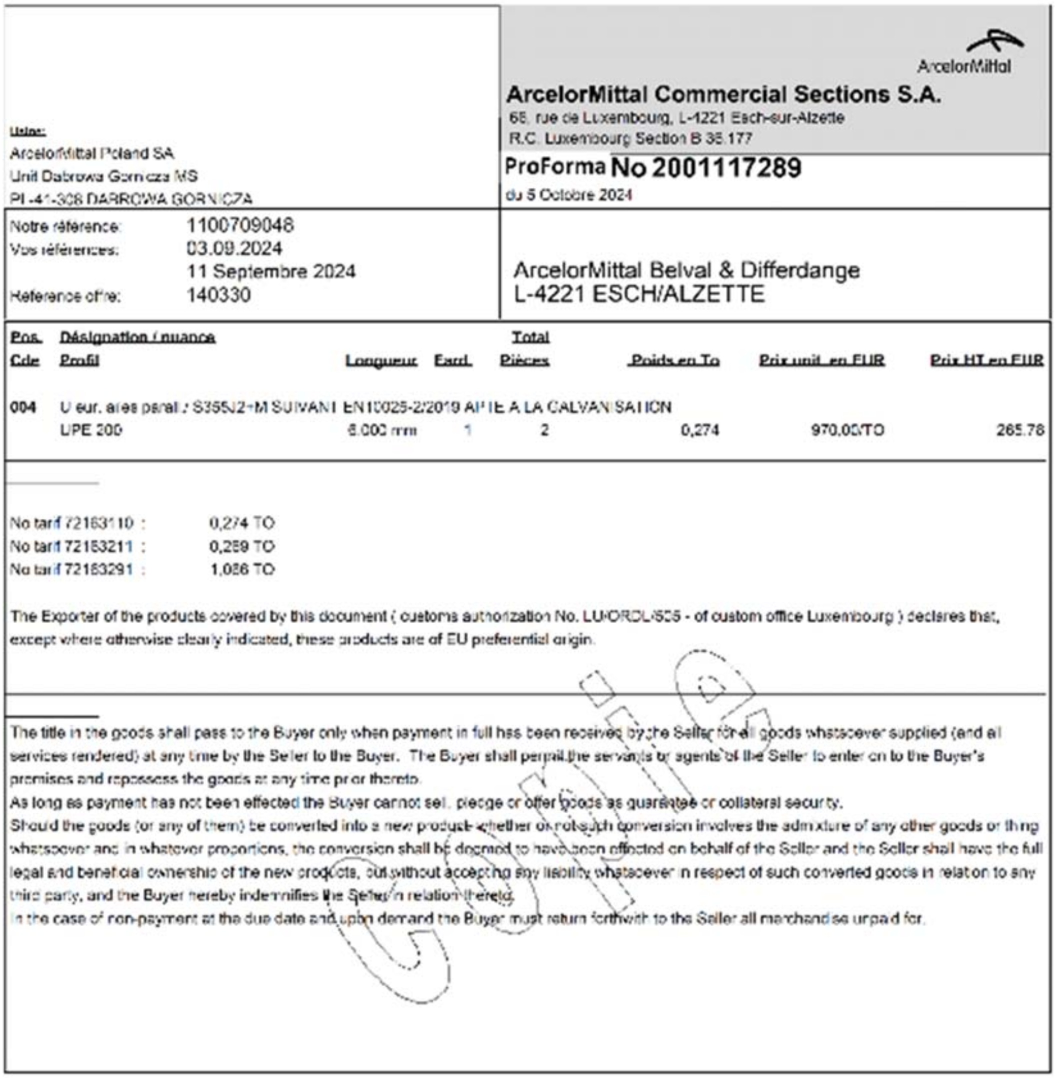
T3.5.6. Reclaimed steel components for reuse, M13-M17

Following a market assessment of steel components for recycling and/or reclaimed, suitable for reuse, FCE initiated contact with several companies involved in ongoing steel structure dismantling projects for procurement purposes. Among these companies are Baumit and Iva Procesna Oprema from Aranđelovac, along with GRAPPS from Smederevo. Site visits were conducted to identify suitable steel components. Reclaimed steel components for reuse were transported to Evrobrod Ltd in Zrenjanin for the fabrication of structural components for prototype and pilot houses.

Figure 3.3-37 - Steel components suitable for reuse

T3.5.7. New steel sections and profiled steel sheeting, M15-M22

New products made from steel grade S355 were ordered and dispatched from ArcelorMittal Poland SA. New steel products (steel sections) were transported to Evrobrod Ltd in Zrenjanin for the fabrication of structural components for prototype and pilot houses.



ArcelorMittal

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ProForma No 2001117289
du 5 Octobre 2024

Notre référence: 1100709048
Vos références: 03.09.2024
11 Septembre 2024
Reference offre: 140330

ArcelorMittal Belval & Differdange
L-4221 ESCH/ALZETTE

Pos. Cde	Désignation / nuance Profil	Longueur	Fard.	Total Pièces	Poids en To	Prix unit. en EUR	Prix HT en EUR
004	U eur. ailes paral.: S355J2+M SUIVANT EN10025-2/2019 APTE A LA GALVANISATION UPE 200	6.000 mm	1	2	0,274	970,00/TO	265,78

No tarif 72163110 : 0,274 TO
No tarif 72163211 : 0,259 TO
No tarif 72163291 : 1,086 TO

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In the case of non-payment at the due date and upon demand the Buyer must return forthwith to the Seller all merchandise unpaid for.

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Figure 3.3-38 - Example of proforma for new steel products

T3.5.8. Recycled aggregate concrete-RAC casting and testing, M16-M19

Testing of recycled concrete aggregate water absorption, particle size distribution and density was performed. Twelve different concrete mixture design were made to initially test workability and compressive strength of recycled aggregate concrete and natural aggregate concrete.

	Vreme upijanja: 24h								
0	neusaglašenost vage nakon 24h	m_{nv}=	0.0	g					
1	masa agregata nakon sušenja	m_{dry}=	1033.9	g					
2	masa SSD agregata	m_{ssd}=	1069.8	g					
3	masa agregata i korpice u vodi, t=1min	M_{1m}=	1210.0	g	Δm_w=	18.22	g	a=	1.762 %
	masa agregata i korpice u vodi, t=5min	M_{5m}=	1212.4	g	Δm_w=	20.62	g	a=	1.994 %
1	masa agregata i korpice u vodi, t=10min	M_{10m}=	1220.2	g	Δm_w=	28.42	g	a=	2.749 %
2	masa agregata i korpice u vodi, t=15min	M_{20m}=	1220.2	g	Δm_w=	28.42	g	a=	2.749 %
3	masa agregata i korpice u vodi, t=30min	M_{30m}=	1221.3	g	Δm_w=	29.52	g	a=	2.855 %
4	masa agregata i korpice u vodi, t=24h	M_{24h}=	1227.7	g	Δm_w=	35.92	g	a=	**3.474** %
5	masa koprice u vodi	M_{korp}=	584.7	g					
6	masa zasićenog agregata u vodi	M_{SSD}=	1227.7	g					
7	zapreminska masa SSD ($m_{ssd}/(m_{ssd}-M_{86400})$)	γ_{ssd}=	2.5066	kg/m^3					
8	zapr. m suvog uzorka ($m_{dry}/(m_{ssd}-M_{86400})$)	γ_{dry}=	2.4224	kg/m^3					

	Vreme upijanja: 24h								
0	neusaglašenost vage nakon 24h	m_{nv}=		g					
1	masa agregata nakon sušenja	m_{dry}=	2401.9	g					
2	masa SSD agregata	m_{ssd}=	2493.2	g					
3	masa agregata i korpice u vodi, t=1min	M_{1m}=	2316.9	g	Δm_w=	49.4	g	a=	2.057 %
4	masa agregata i korpice u vodi, t=2min	M_{2m}=		g	Δm_w=	-2267.5	g	a=	%
5	masa agregata i korpice u vodi, t=3min	M_{3m}=	2318.4	g	Δm_w=	50.9	g	a=	2.119 %
6	masa agregata i korpice u vodi, t=4min	M_{4m}=	2319.3	g	Δm_w=	51.8	g	a=	2.157 %
7	masa agregata i korpice u vodi, t=5min	M_{5m}=	2326.2	g	Δm_w=	58.7	g	a=	2.444 %
8	masa agregata i korpice u vodi, t=10min	M_{10m}=	2329.3	g	Δm_w=	61.8	g	a=	2.573 %
9	masa agregata i korpice u vodi, t=15min	M_{15m}=	2330.4	g	Δm_w=	62.9	g	a=	2.619 %
10	masa agregata i korpice u vodi, t=30min	M_{30m}=	2332.0	g	Δm_w=	64.5	g	a=	2.685 %
11	masa agregata i korpice u vodi, t=1h	M_{1h}=	2334.1	g	Δm_w=	66.6	g	a=	2.773 %
12	masa agregata i korpice u vodi, t=24h	M_{24h}=	2358.8	g	Δm_w=	91.3	g	a=	**3.801** %
13	masa koprice u vodi	M_{korp}=	854.5	g		-1413			-58.82843
14	masa zasićenog agregata u vodi	M_{SSD}=	2358.8	g					
15	zapreminska masa SSD ($m_{ssd}/(m_{ssd}-M_{86400})$)	γ_{ssd}=	2.5212	kg/m^3					
16	zapr. m suvog uzorka ($m_{dry}/(m_{ssd}-M_{86400})$)	γ_{dry}=	2.4289	kg/m^3					

Figure 3.3-39 - Recycled concrete aggregate water absorption and density

RECEPTURE ZA 1m³ BETONA - Probna mešavina za CircBoost														
Sifra betona	Oznaka betona	m_v [kg/m³]	Količine agregata po frakcijama FNA [0/4]	CAN [4/8]	CAN [8/16]	m_c [kg/m³]	m_{plast} [kg/m³]	m_{fi} [kg/m³]	$\omega_{eff}=m_v/m_b$	2540.7 Σ	2700 I	2442 II	2429 III	V (L)
1	**RAC_300/20_0.60**	**180.0**	**669.9**	**418.7**	**586.2**	**300.0**	**1.500**	**60.0**	**0.60**	**1674.7**	**40.0**	**25.0**	**35.0**	**1000.00**
						0.600								
	uvuceni vazduh	4	%											
Povecanje mase agregata zbog vlaznosti							Agregat:		Prva frakcija recni (Penta), druga i treca RCA Vinca					
			FNA [0/4]	CAN [4/8]	CAN [8/16]		Stanje:		Prva frakcija prirodno vlazna					
	$m_i' = m_i * (1+H^i)=$		683.29	422.87	592.60				Druga i treca frakcija prirodno vlazne					
							Vlaznost:		Prva		%			
Smanjenje vode usled vlaznosti i upijanja agregata									Druga		%			
		Δm_v		7.00	l				Treca		%			
	$\Delta m = \Sigma\, m_i * (H^i - a_i)=$	-8.30		-0.058	kg									

RECEPTURE ZA 1m³ BETONA - SA VLAŽNIM AGREGATOM														
Sifra betona	Oznaka betona	m_v [kg/m³]	Količine agregata po frakcijama FNA [0/4]	CAN [4/8]	CAN [8/16]	m_c [kg/m³]	m_{plast} [kg/m³]	m_{fi} [kg/m³]	$\omega_{eff}=m_v/m_b$	Σ	I	II	III	V (L)
1	**RAC_300/20_0.60**	**188.3**	**683.29**	**422.87**	**592.60**	**300.0**	**1.500**	**60.0**	**0.500**	**1698.8**	**40.2**	**24.9**	**34.9**	**1000.00**

RECEPTURE ZA JEDNU MESALICU BETONA - SA VLAŽNIM AGREGATOM														
Sifra betona	Oznaka betona	m_v [kg/m³]	Količine agregata po frakcijama FNA [0/4]	CAN [4/8]	CAN [8/16]	m_c [kg/m³]	m_{plast} [kg/m³]	m_{fi} [kg/m³]	$\omega_{eff}=m_v/m_b$	Σ	I	II	III	V (L)
1	**RAC_300/20_0.60**	**1.318**	**4.783**	**2.960**	**4.148**	**2.100**	**0.011**	**0.420**	**0.500**	**11.9**	**40.2**	**24.9**	**34.9**	**7.00**
	voda za upijanje agregata	58.088	g	7.108										
	voda za hidrataciju	1260	g											

Figure 3.3-40 - Recycled concrete aggregate mixture design

Figure 3.3-41 - Concrete workability testing (left), and compressive strength testing (right)

T3.6. Production of prototype (FCE, PENTA, EBR), M10-M30

T3.6.1. Formwork production and reinforcement installation, M17-M22

Formwork and reinforcement layouts and details for reinforced columns and walls were developed together with PENTA.

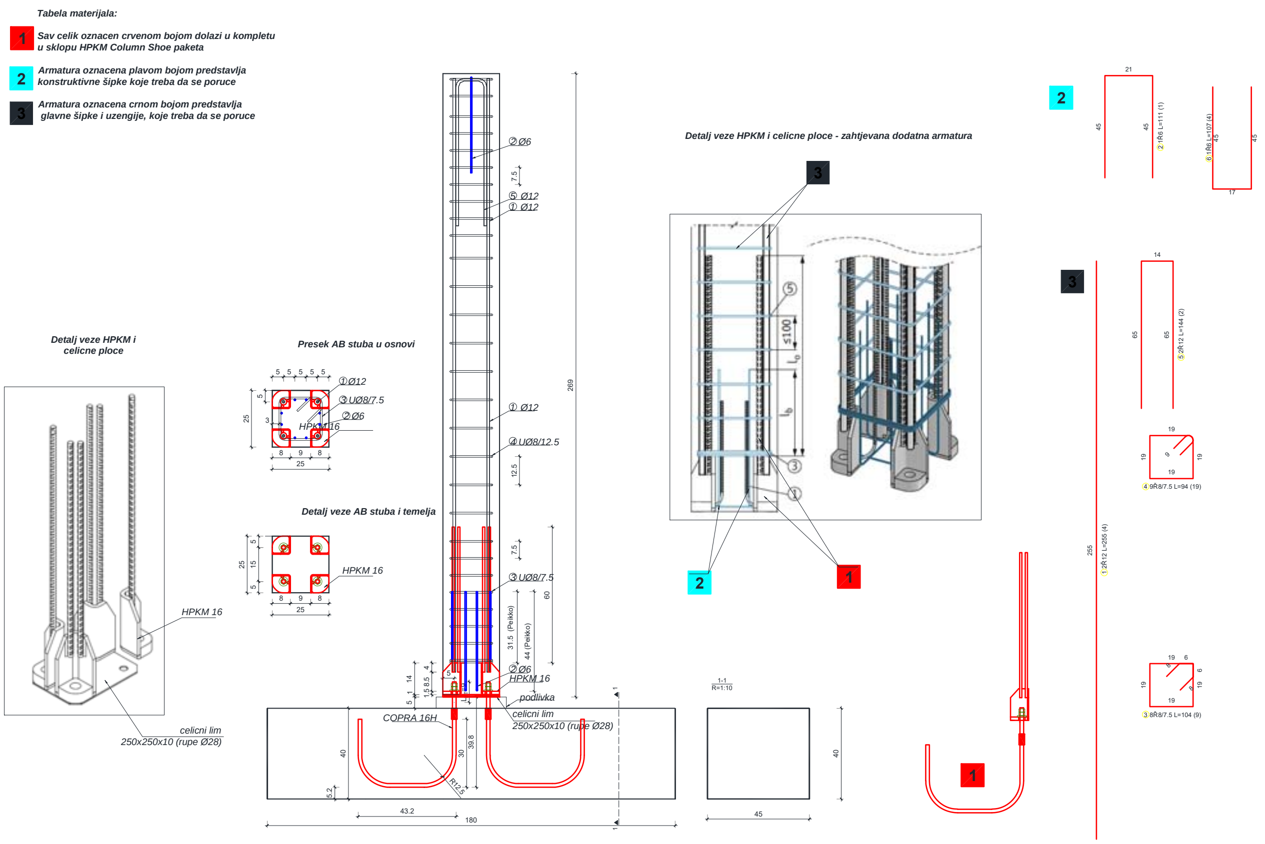


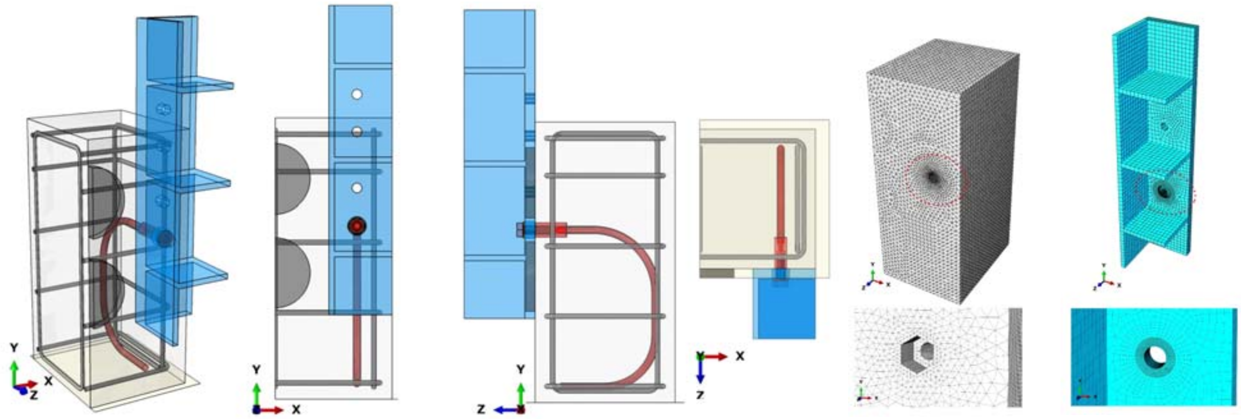
Figure 3.3-42 - Formwork and reinforcement layout of one concrete column

T3.6.2. Numerical prototype simulation of pilot house elements, M10/M21

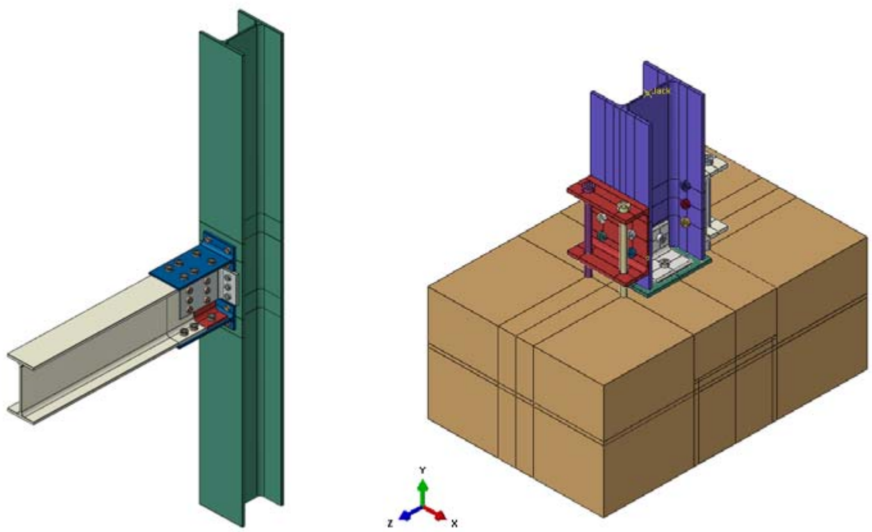
Preliminary prototype testing was done on numerical models of main elements and connection types. The production of numerical models was done in Abaqus, and some models are shown below. Numerical testing was designed to determine the dimension of all elements, reinforcement, the behaviour of joints and initial failure modes. This analysis together with parametric study will define the prototypes for experimental testing.

Preliminary FE analysis utilizing Abaqus software was conducted to effectively structure the experiment, including the test matrix and setup and arrangement of measurement instruments (designed to monitor the failure mechanisms of various joint components). This approach allowed for the assessment of the ultimate moment resistance, rotational stiffness, and capacity of the joints under investigation.

1. Concrete elements and connections



2. Steel elements and connections



3. Brick infill wall and rubber

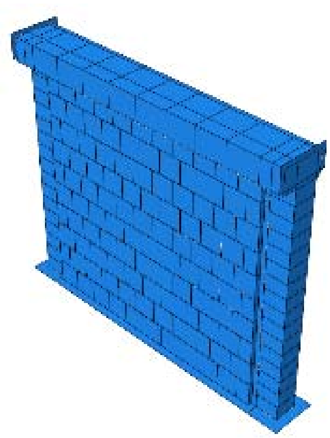


Figure 3.3-43 - Geometry of numerical models representing demountable joints for prototype testing

T4. Pilots' technical evaluation (FCE), M12-M45

T4.1. Prototype testing, M12-M34

T4.1.1. Numerical testing of house prototype, M12-M21

1. Numerical testing of demountable connector with demountable bolt/threaded bar, embedded mechanical coupler and rebar anchor.

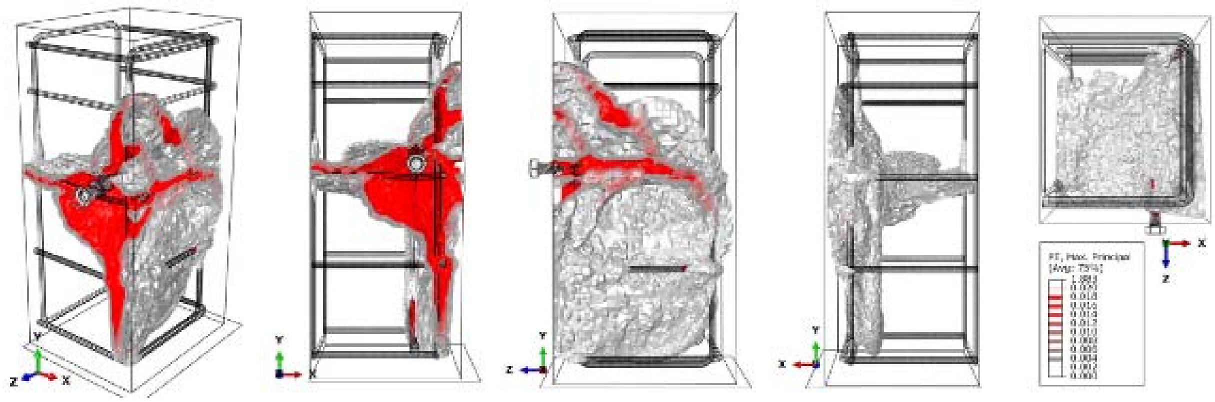


Figure 3.3-44 - Failure mode and cracks in concrete element

2. Beam-to-column steel joint

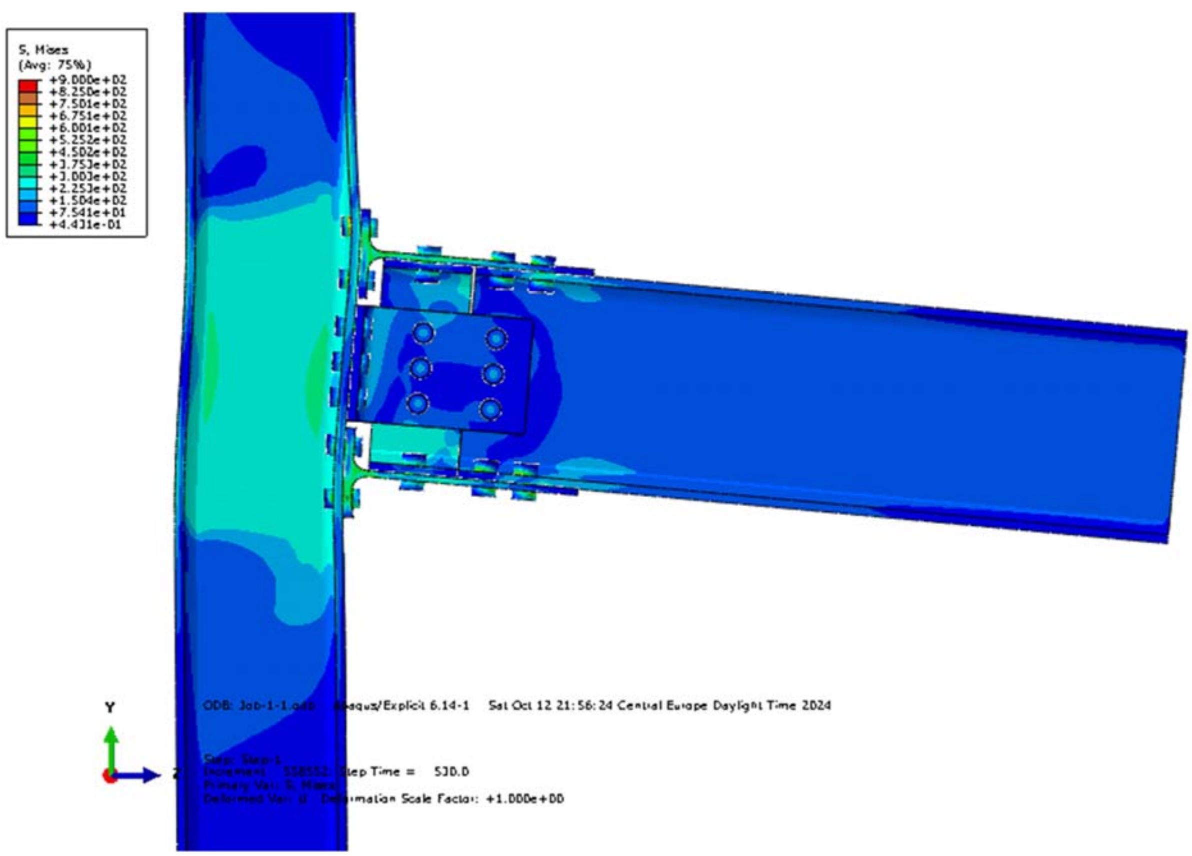


Figure 3.3-45 - Deformation of the moment-resisting beam-to-column steel joint

3. Numerical testing of infill brick walls with INODIS rubber connection

Start of damage at 2% drift

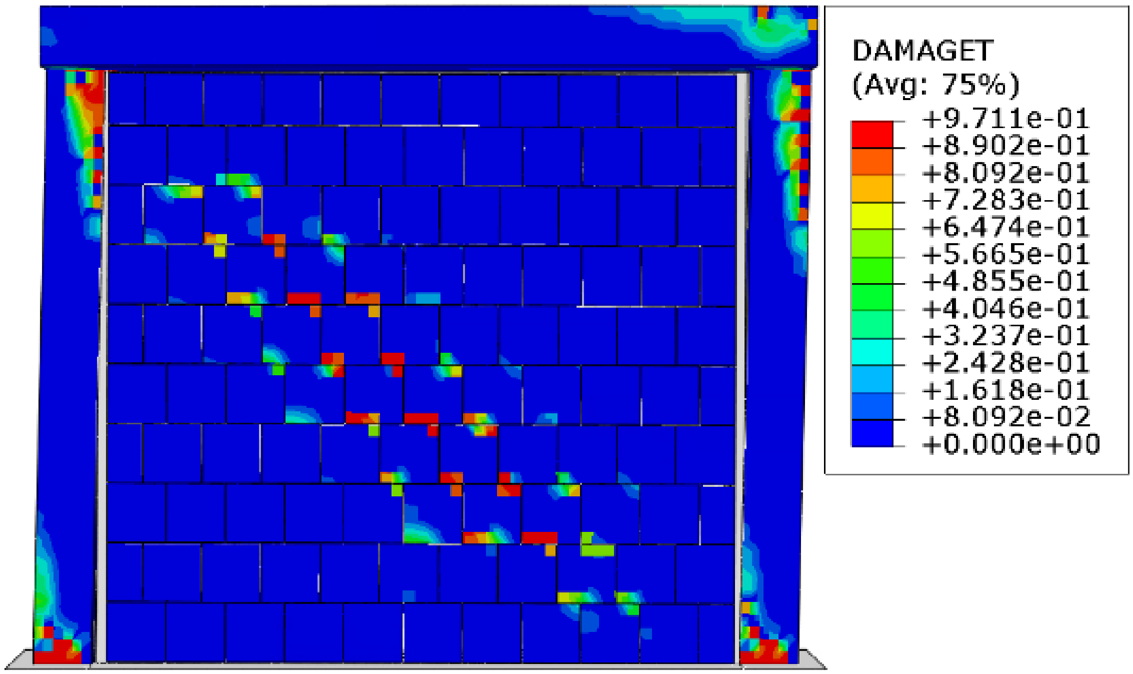


Figure 3.3-46 - Bending moment comparison of bare frame and infilled frame with INODIS rubber connection showing now influence of interaction due to infill wall

T4.1.2. Development of the test set-up, M17-M28

Test set-up for reinforced concrete columns and frames without and with brick infill

Testing of prototype reinforced concrete columns and frames without and with brick infill is planned to take place at the Laboratory for Materials and Structures at the FCE. Testing will be designed to simulate operational loads: axial to simulate gravitational loads (self-weight of elements, live loads, snow) and transversal loads (wind and earthquake).

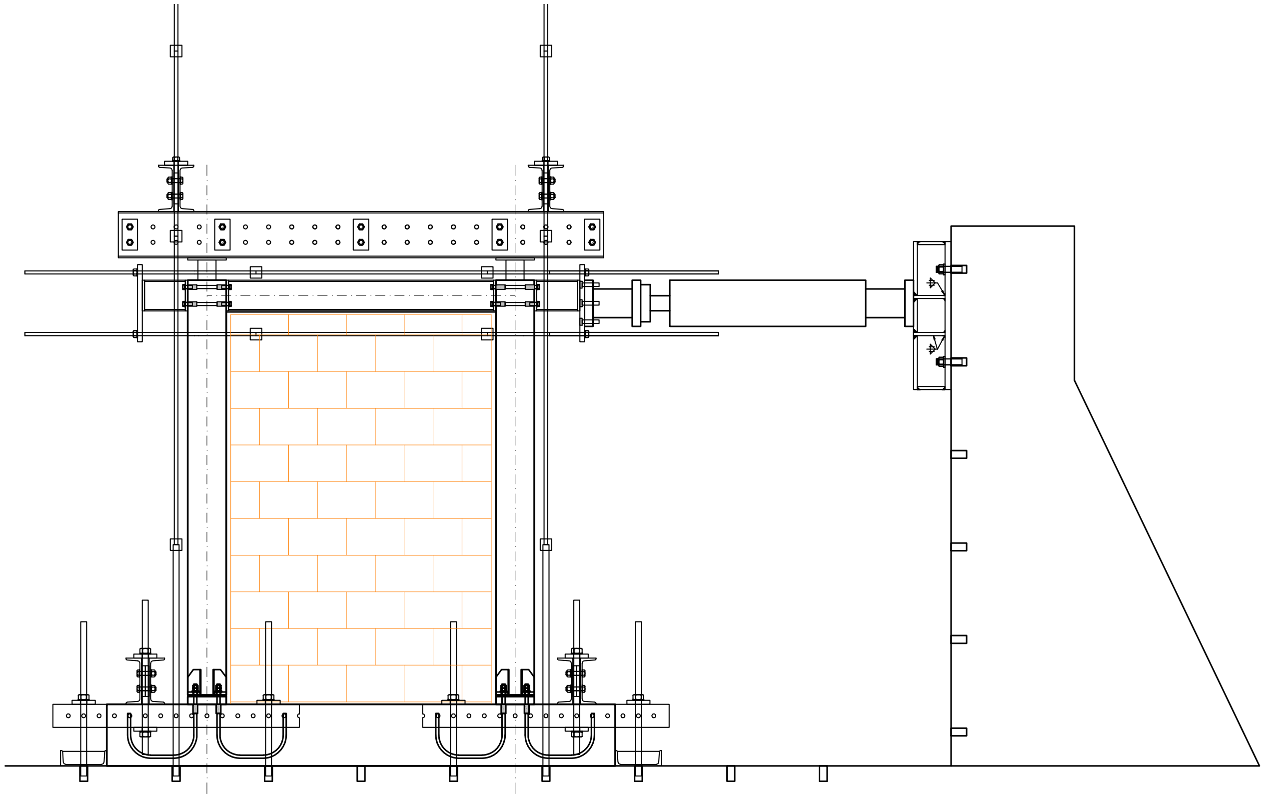


Figure 3.3-47 - Test setup for RC-steel frame with brick infill prototype

Test setup for moment-resisting joint prototype

The experimental program includes three tests, all utilizing the same joint configuration but varying in steel grades, bolt arrangements and Tee-flange components. The test setup was defined considering the prototype joint design and arrangement of the laboratory equipment. The load should be applied on the beam free end which is laterally restrained, whereas the column ends are pin-supported to the rigid frame. Deformations and strains should be continuously monitored using linear variable displacement transducers and strain gauges, complemented by a digital image correlation system for enhanced data accuracy.

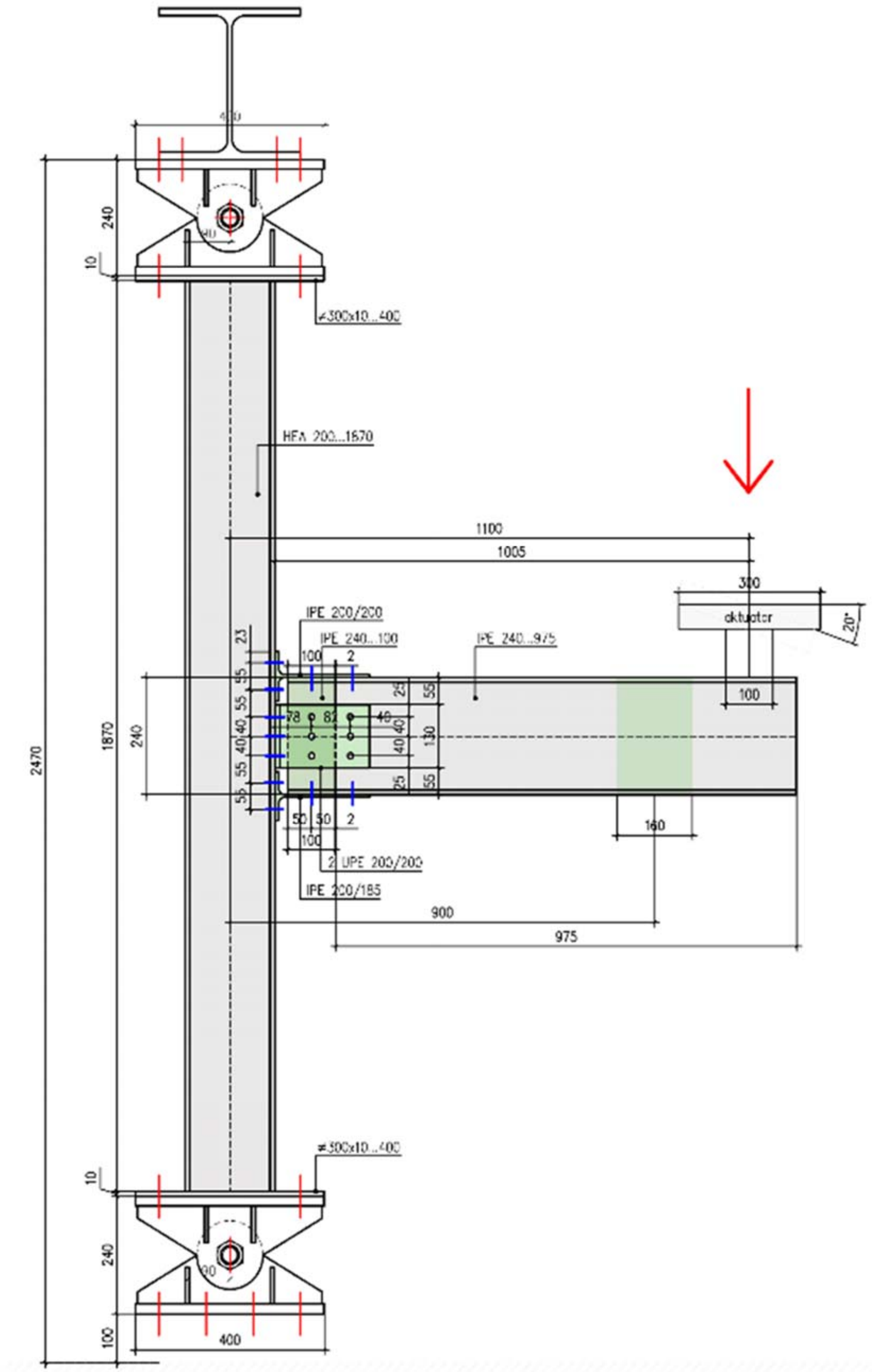


Figure 3.3-48 - Test setup

3.3.3 Progress according to the Pilot operational plan

Some changes of activities duration were made after Operational plan was made, and new and detailed plan was made at that time. Nevertheless, all major activities planned for this reporting period have been completed: equipment has been acquired and deployed, or for some small pieces in the finishing process; initial meetings with partners and stakeholders have been conducted; architectural and conceptual structural design have been done; detailed structural design of 3R house was done together with partners; database of potential sources of recycled and reusable materials was made; material procurement has been done; numerical prototype production and testing was performed; physical prototype has not been produced yet. That means that the first two milestones have been reached according to the PDS, while a postpone of the milestone 3 is proposed.

Table 3.3-2 - Pilot 3 Milestones

#	Name	Month	How you know you reached it
1	Equipment acquisition	3	Equipment setup at FCE, invoices paid
2	Pilot projects detailly planned	6	POP sent to WP3 leader, i.e. D3.1 Pilot deployment strategy delivered
3	Prototype ready for testing	18→24	Material procurement finished, Prototype of key structural set of elements produced, i.e. D3.2 – PILOT year 1 report - delivered
4	Structural elements ready for assembling	30	Testing of prototype in lab completed, connections (joints) verified, i.e. D3.3 - PILOT year 2 report delivered
5	Operational testing completed	45	Report about in-situ testing delivered

3.3.4 Update of the operational plan

Activities listed in Pilot operational plan (given in Pilot Deployment Strategy) were further planned in more detail in M7-M8. During this planning, all tasks were divided into smaller subtasks, and the duration of some activities was changed, Table 3.3-3. The largest change in duration of activities was in the equipment acquisition and deployment. After market research was completed, it was clear that the specific equipment planned for this project needed more time to be constructed and transported to Serbia. Also, strict regulations regarding purchases for public entity, like FCE, usually prolong acquisition and employment time, especially if seller is not from Serbia. Having this in mind, new timeline for equipment acquisition and deployment was adopted. All equipment that is being purchased within this project is needed for experimental testing planned for new reporting periods. From five pieces of equipment that were planned for this project, three were acquired and deployed. Two remaining pieces of smaller equipment are in the process of acquisition, and they are expected to be deployed in January 2025. Those two pieces are needed for house operational testing planned for M37-M45, so there are not on the critical path. Detailed timeline for all activities that was followed during this reporting period is shown below.

Detailed plan for the next reporting period M18-M30 is made and shown in the Table 3.3-4.

Table 3.3-3 – Updated Timeline for the period M1-M18

		Tasks and activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
			Jun	Jul	Aug	Sep	Okt	Nov	Dec	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec
M1-M5	T1	**Pilots operation plan and evaluation methodology (M1 - M4)**				M2-D3.1															
M1-M4	T1.1	**Pilot operational plan**																			
M4-M5	T1.2	**Evaluation methodology**																			
M1-M7	T2	**Establish pilot baselines (M1-M7)**																			
M4-M5	T2.1	**SoA for each solution**																			
M1-M4	T2.2	**Initial meetings with pilot's partners and potential end-users and stakeholders**																			
M5-M6	T2.3	**Establishing baselines**																			
M6-M7	T2.4	**Comaprison between pilots**																			
M1-M42	T3	**Pilots deployment (M6-M42)**																		M5-D3.2	
M1-M21	T3.1	**Equipment acquisition and deployment**																			
M4-M7	T3.2	**Architectual design of the house and conceptual structural design**																			
M8-M28	T3.3	**Detailed structural design together with partners**																			
M8-M20	T3.3.1	Design of concrete columns, walls and foundations for prototype testing																			
M17-M28	T3.3.2	Design of composite slab																			
M17-M18	T3.3.3	Design of rubber connection for infill walls for prototype testing																			
M14-M17	T3.3.4	Design of demountable joints for prototype testing																			
M9-M18	T3.4	**Database of potential sources of recycled and reusable materials**																			
M6-M25	T3.5	**Material procurement (RCA, fly ash, recycled rubber, connectors and other) and concrete design**																			
M6-M13	T3.5.1	Recycled concrete aggregate-RCA																			
M21-M25	T3.5.2	Fly ash																			
M10-M19	T3.5.3	Old/used bricks																			
M22-M25	T3.5.4	Recycled rubber																			
M18-M21	T3.5.5	Connectors																			
M13-M17	T3.5.6	Reclaimed steel components for reuse																			
M15-M22	T3.5.7	New steel sections and profiled steel sheeting																			
M16-M19	T3.5.8	Recycled aggregate concrete-RAC casting and testing																			
M23-M29	T3.5.9	Fly ash concrete-FAC casting and testing																			
M10-M40	T3.6	**Production of prototype**																			
M17-M22	T3.6.1	Formwork production and reinforcement instalation																			
M10-M21	T3.6.2	Numerical prototype simulation of pilot house elements																			
M22-M24	T3.6.3	Sample casting at Penta - part 1: NAC columns																			
M24-M26	T3.6.4	Sample casting at Penta - part 2: RAC columns																			
M27-M34	T3.6.5	Production of frame prototype (made of 2RAC columns and one steel beam and bottom beam)																			
M25-M34	T3.6.6	Production of infill walls																			
M18-M21	T3.6.7	Moment-resisting joint prototype fabrication																			
M23-M25	T3.6.8	Column base joint prototype fabrication																			
M23-M30	T3.6.9	Composite slab-to-steel beam connection																			
M24-M41	T3.7	**Production of house elements**																			
M25-M40	T3.7.1	RC columns, walls and foundations																			
M24-M40	T3.7.2	Steel frame elements																			
M34-M39	T3.7.3	Composite slab on the profile steel sheeting with FAC																			
M28-M36	T3.7.4	Infill walls																			
M36-M39	T3.7.5	Floor slab																			
M36-M43	T3.8	**House construction**																			
M1-M48	T3.9	**Demonstration and promotion activities**																			
M12-M45	T4	**Pilots' technical evaluation**																			
M12-M34	T4.1	**Prototype testing**																			
M12-M21	T4.1.1	Numerical testing of house prototype																			
M17-M28	T4.1.2	Development of the test set-up																			
M18-M23	T4.1.3	Small scale tests on brick/concrete/steel/rubber connection																			
M19-M22	T4.1.4	Trial testing of the equipment																			
M23-M25	T4.1.5	Testing of NAC columns																			
M24-M26	T4.1.6	Analysis of the results for NAC columns																			
M25-M34	T4.1.7	Testing of RAC columns																			
M27-M36	T4.1.8	Analysis of the results for RAC columns																			
M27-M37	T4.1.9	Testing of RAC frames																			
M28-M39	T4.1.10	Analysis of the results for RAC frames																			
M30-M39	T4.1.11	Testing of infilled frames																			
M32-M40	T4.1.12	Analysis of the results for infilled frames																			
M19-M22	T4.1.13	Testing of moment-resisting beam-to-column joints, Data processing																			
M22-M24	T4.1.14	Numerical simulations, Parametric studies, Data analysis for moment-resisting beam-to-column joints																			
M24-M26	T4.1.15	Testing of column base joints, Data processing																			
M27-M29	T4.1.16	Numerical simulations, Parametric studies, Data analysis for column base joints																			
M28-M35	T4.1.17	Composite slab-to-steel beam connection demonstration																			
M30-M40	T4.1.18	Result discussions and final Conclusions																			
M347-M45	T4.2	**In-situ testing of house and its elements**																			
M38-M43	T4.3	**House assembly and dissasembly**																			
M12-M45	T4.4	**"Horizontal" activities through the other WPs**																			

Table 3.3-4 – Timeline for the next reporting period, M18-M30

	Tasks and activities	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		Nov	Dec	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec
T1	**Pilots operation plan and evaluation methodology (M1 - M4)**														
T1.1	**Pilot operational plan**														
T1.2	**Evaluation methodology**														
T2	**Establish pilot baselines (M1-M7)**														
T2.1	**SoA for each solution**														
T2.2	**Initial meetings with pilot's partners and potential end-users and stakeholders**														
T2.3	**Establishing baselines**														
T2.4	**Comaprison between pilots**														
T3	**Pilots deployment (M6-M42)**	M5 D3.2												M5- D4.4	
T3.1	**Equipment acquisition and deployment**														
T3.2	**Architectual design of the house and conceptual structural design**														
T3.3	**Detailed structural design together with partners**														
T3.3.1	Design of concrete columns, walls and foundations for prototype testing														
T3.3.2	Design of composite slab														
T3.3.3	Design of rubber connection for infill walls for prototype testing														
T3.3.4	Design of demountable joints for prototype testing														
T3.4	**Database of potential sources of recycled and reusable materials**														
T3.5	**Material procurement (RCA, fly ash, recycled rubber, connectors and other) and concrete design**														
T3.5.1	Recycled concrete aggregate-RCA														
T3.5.2	Fly ash														
T3.5.3	Old/used bricks														
T3.5.4	Recycled rubber														
T3.5.5	Connectors														
T3.5.6	Reclaimed steel components for reuse														
T3.5.7	New steel sections and profiled steel sheeting														
T3.5.8	Recycled aggregate concrete-RAC casting and testing														
T3.5.9	Fly ash concrete-FAC casting and testing														
T3.6	**Production of prototype**														
T3.6.1	Formwork production and reinforcement instalation														
T3.6.2	Numerical prototype simulation of pilot house elements														
T3.6.3	Sample casting at Penta - part 1: NAC columns														
T3.6.4	Sample casting at Penta - part 2: RAC columns														
T3.6.5	Production of frame prototype (made of 2RAC columns and one steel beam and bottom beam)														
T3.6.6	Production of infill walls														
T3.6.7	Moment-resisting joint prototype fabrication														
T3.6.8	Column base joint prototype fabrication														
T3.6.9	Composite slab-to-steel beam connection														
T3.7	**Production of house elements**														
T3.7.1	RC columns, walls and foundations														
T3.7.2	Steel frame elements														
T3.7.3	Composite slab on the profile steel sheeting with FAC														
T3.7.4	Infill walls														
T3.7.5	Floor slab														
T3.8	**House construction**														
T3.9	**Demonstration and promotion activities**														
T4	**Pilots' technical evaluation**														
T4.1	**Prototype testing**														
T4.1.1	Numerical testing of house prototype														
T4.1.2	Development of the test set-up														
T4.1.3	Small scale tests on brick/concrete/steel/rubber connection														
T4.1.4	Trial testing of the equipment														
T4.1.5	Testing of NAC columns														
T4.1.6	Analysis of the results for NAC columns														
T4.1.7	Testing of RAC columns														
T4.1.8	Analysis of the results for RAC columns														
T4.1.9	Testing of RAC frames														
T4.1.10	Analysis of the results for RAC frames														
T4.1.11	Testing of infilled frames														
T4.1.12	Analysis of the results for infilled frames														
T4.1.13	Testing of moment-resisting beam-to-column joints, Data processing														
T4.1.14	Numerical simulations, Parametric studies, Data analysis for moment-resisting beam-to-column joints														
T4.1.15	Testing of column base joints, Data processing														
T4.1.16	Numerical simulations, Parametric studies, Data analysis for column base joints														
T4.1.17	Composite slab-to-steel beam connection demonstration														
T4.1.18	Result discussions and final Conclusions														
T4.2	**In-situ testing of house and its elements**														
T4.3	**House assembly and dissasembly**														
T4.4	**"Horizontal" activities through the other WPs**														
			2024	2025											2025

3.3.5 Lessons learnt and next steps

The overall success rate of this Pilot 3 is very high. Most important lessons learnt in this first reporting period are:

- Equipment acquisition for public entities takes a long period of time for special types of equipment, especially if they are purchased abroad.
- Recycled and reused construction materials are not so easy to find in Serbia. Market is not developed, but some initiatives in practise exist. This pilot project should put an extra effort to help the development of this local market.

3.4 Implementation of the Pilot 4 – Vesterlen

3.4.1 Summary

3.4.1.1 Objectives

The overall objective of the pilot is to demonstrate the entire circular building process "from demolition to construction" consisting of the demolition stage, production of quality RCA stage and construction stage.

- **Demolition stage**: detail mapping of concrete part of structures prior to demolition (use of innovative method to preciously evaluate and minimize the quantity of concrete labelled as contaminated), employing selective demolition and sorting of recyclable and contaminated concrete.
- **Production of quality RCA stage:** use of modern machinery and modern crushing and sorting techniques, certification and properties evaluation
- **Construction stage:** logistics connected to RCA transportation and adjustment of the concrete mix during production.

In Norway, there is Kontrollrådet, the Norwegian Control Council, which administers certifications within the building materials sector and, in the case of RCA production, approves the system for the production of RCA. After production, certification for RCA is mainly described in 3 documents that refer to the use of RCA in concrete production. Two of them are EU standards NS-EN 206:2013+A2+NA Specification, performance, production and conformity Betong Spesifikasjon, egenskaper, framstilling og samsvar and NS-EN 12620:2002+A1+NA Tilslag for betong Aggregates for concrete, both extended by Norwegian annex where the RCA requirements (max or mix allowed value for certain properties, need for declaration of properties), classification (two groups NA and NB), and quantities allowed in concrete (for fraction 0-4 mm and ≥ 4 mm and in NA and NB quality). The third document that is very often used by the industry is Norsk Betongforening, NB Publikasjoner no. 18 Tilslagsmaterialer for betongformål (1988), which is presently under revision. Iveta Novakova from UiT provided robust data about RCA, and also participated in revisions of the new version.

3.4.1.2 General information about work done in the 1st year

The first year of pilot 4 was mainly focused on planning and obtaining permits for all activities. Sortland municipality became a crucial stakeholder, providing the demolition object and coordinating the activities connected to building the new Gaia museum. Furthermore, discussions were held with local politicians and the public to get support for the entire action. The pre-demolition audit was enriched by detail mapping of concrete parts of the structure conducted by UiT; mapping also of core drilling, and those samples were further tested at UiT concrete laboratory for recyclability potential. Activities connected to demolition are the largest but there I also lot of progress on Gaia museum design and selection of concrete with RCA and needed quantities. Production of RCA is closely connected to demolition, and RENO is taking the initiative to arrange the whole process according to the regulation, especially concerning noise and dust during production.

3.4.2 Main activities and results

T1 PILOTS OPERATION PLAN AND EVALUATION METHODOLOGY, M1 - M31

T2 Establish pilot baselines (M1-M6)

All tasks and activities within the task T1 (T1.1 to T1.5) and task T2 (T2.1, T2.2 and T2.3) have been done and the outcomes were embedid in the project documents – Pilot Operational Plan and Baselines which form the Pilot Deployment Strategy. Task T1.6: Reporting, will be executed continuously during the project life in intervals defined by GA.

T3 Pilots deployment (M6-M42)

T3.4 Demonstration and promotion activities

Promotion activities are reported mainly within WP2 and WP8

T4 Pilots' technical evaluation (M12-M45)

Technical evaluation is done continuously when all ther activitiies – demolition, production of RCA and construction of Gaia is progressing and changing acording to actual informations.

T4.1 Summarising the efficiency of selective demolition

Predemolition audit leads towards efficient selective demolition. The assessment of the selective demolition will be done after the demolition takes place.

T3.1 Demolition stage - mapping, planning, conduction of selective demolition, sorting of CDW

Demolition of objects in Sortland is delayed due to political situations in the municipality, and despite it being the post point, the entire period was used for detail mapping and tomorrow planning. Also, the tender for the demolition company was developed and published, and offers were obtained. Now the demolition is approved and scheduled for 2025.

The initial stage of the circular building process is the demolition of the existing structure, including the pre-demolition activities to obtain necessary information about the structure, materials, as well as potential hazards, to determine the potential of recyclability, and to plan the selective demolition. The building deemed for demolition is an old slaughterhouse "Nortura" building owned by the Sortland municipality, that was built in the 1960 and remodeled two times in 1982 and 1998. It spreads over 7300 m2 surface area and contains several distinct parts. The consequence of the remodels is that the structure has different materials, including several types of concrete, steel, wood, glass, rubber, etc. The first step was obtaining all existing documentation and performing detailed assessment and evaluation of the structure. The assessment implied reviewing the documentation, performing visual inspection, comparing the geometry given in the documentation and on site, establishing what materials were used for the structural elements, and evaluating their condition. Environmental mapping was completed by extensive analysis of the concrete structure consisting of strength testing of concrete elements with Schmidt hammer and extracting concrete core samples for assessment of element composition. Types of concrete which have been observed are regular concrete, lightweight expanded clay aggregate concrete, and lightweight air-entrained concrete. Environmental mapping implied reviewing the installed covers, paints, pipes, win-dows, doors, walls of the freezers, rooms where the animals were kept before and after slaughtering, etc. The resulting report was useful in determining possible contaminations of the concrete. Moreover, chloride attack was spotted during the visual inspection in several concrete elements. Rough estimate of the amount of demolition waste gave a total volume of demolition waste of 8760 m3, from which 3550 m3 refers to the concrete, while the rest includes wood, tiles and bricks, glass, metal, polyvinyl chloride, and mixed materials. After obtaining information on the contamination of the concrete and rough esti-mate of the waste, a detailed estimation was made to obtain the volume of non-contaminated concrete. The volume of 717 m3 of the plain structural concrete was obtained after the detailed estimation. Lightweight expanded clay aggregate concrete was additionally estimated in the volume of 79 m^3 that may be reused for groundwork and/or aesthetic applications (architectural concrete was made after crushing this material). In total, five core samples were extracted from structure at different locations within the building. Core samples were prepared and tested for compressive strength and subsequently processed by jaw crusher into RCA. The results showed that most of the elements (beams, columns, walls, and slabs) are made of concrete strength class C30/37 or C35/45 with exception of the bomb shelter made of concrete of higher strength class C70/85 with dense reinforcement, Table 3.4-1. Results from Schmidt hammer indicated the same average strength of concrete, 47.0 MPa with a standard deviation 4.9 MPa. Furthermore, it was observed that different types of concretes were added to the vertical elements over time, creating "sandwich" structures that cannot be reused for recycled aggregate concrete (RAC). Some samples were excluded from the assessment due to the high number of steel rebars present in the sample. The density of sampled concrete is, on average, 2.293±0,069 g/cm3, which is acceptable for the production of RCA. Test RCA production was conducted from core drills used previously for the com-pressive strength test. A laboratory jaw crusher was used, and approximately 18.5 kg of RCA was produced. Results showed increasing water absorption with a smaller fraction which is common, but the shape index points towards a high content of non-cubic particles. Such a result might be caused by high strength or large proportion of the paste of parent concrete. Saturated surface dry density fulfils the requirement to be minimally 2100 kg/m3 besides fraction 4/8 mm. As those are preliminary results, the properties can change for large-scale produced RCA.

Table 3.4-1 – Results of compressive strength tests on concrete cores

Core #	Density [g/cm^3]	Compressive strength [MPa]	Concrete class	Comments
1	2.289	43.63	C30/37	-
2	2.293	41.69	C30/37	-
3	2.34	42.74	C30/37	Three rebars visible
4	2.25	57.78	C45/55	-
5	2.314	91.45	C70/85	One rebar visible
6	2.266	87.15	C70/85	Two cavities from missing rebars
7	2.31	17.14	-*	Five visible rebars and a cavity
8	2.309	19.87	-*	Three visible rebars
9	2.232	26.56	-*	Two rebars inside
10	2.224	28.14	-*	Three visible rebars

* rebars found in the core sample, it is not representative result of concrete quality.

Figure 3.4-1, Figure 3.4-2 and Figure 3.4-3 are from sampling and detail testing of concrete from demolition object.

Figure 3.4-1 - Core sample drilling for detail analysis

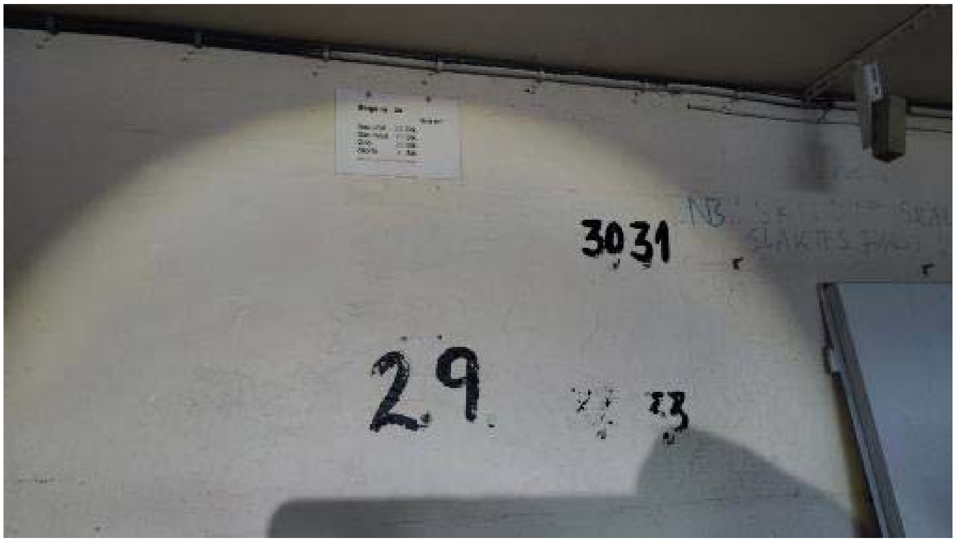


Figure 3.4-2 - Test spots for evaluation of concrete compressive strength by Schmidt hammer

Figure 3.4-3 - Test drills for analyses of material type of individual structure parts

T3.2 Production of RCA stage - process description and logistics

Production of RCA is connected to demolition; therefore, it can not be performed unless the demolition takes place. Due to that, this activity will also be delayed and will take place directly after or during the demolition.

The RCA properties depend on parent concrete (the concrete RCA are produced from) and therefore, it is not possible to generalize their properties unless tested. In order to obtain an initial idea about the RCA properties from demolition concrete of Nortura slaughterhouse, a test RCA production was conducted from core drills used previously for the compressive strength test. A laboratory jaw crusher was used, and approximately 18.5 kg of RCA was produced. Properties such as overall particle size distribution and particle size distribution for individual fractions (0/4 mm, 4/8 mm, 8/16 mm, and 16/22 mm), water absorption, density and shape index were analyzed according to NS-EN 12620 [11]. 73.0% of fraction with particle larger than 4 mm was produced which is very favorable for utilization in concrete production. Results from other tests are in Table 3.4-2.

Table 3.4-2 - Results of density, water absorption, and shape index tests per fraction of RCA

Sieve size [mm]	Saturated surface dried particle density [g/cm3]	Water absorption [%]	Shape index [-]	
0/4	2.202	10.59	-	-
4/8	2.045	6.79	52.17	SI40
8/16	2.154	7.29	47.32	SI55
16/22	2.10	6.71	29.83	SI55

Results showed increasing water absorption with a smaller fraction that is common, but the shape index points towards a high content of non-cubic particles. Such a result might be caused by high strength or large proportion of the paste of parent concrete [12]. Saturated surface dry density fulfil requirement to be minimally 2100 kg/m3 besides fraction 4/8 mm [13]. As those are preliminary results, the properties can change for large-scale produced RCA.

Location of RCA production

The application of CDW for reuse or recycling is primarily facilitated to reduce the carbon footprint of the new construction, as well as to reduce the landfilling. However, carbon footprint involves other factors, not only the production of new concrete. Transportation of raw materials presents a high carbon emitter, especially in sparse regions with long travel distances such as the Arctic. If not planned properly, the demolition could involve transporting the materials several times, raising the footprint to the same level as new construction.

Production of RCA from demolished concrete can be continuous when the concrete from the demolition site and other waste streams is transported to a single location and continuously processed, or it can be discontinuous when it takes place directly at the demolition site using a mobile crusher and a sieve system. In case of the Nortura building, a mobile crusher will be used to enable the production of RCA at the demolition site. This leaves the question of the location of RCA production open for discussion. Since the amount of the RCA needed for the construction of the new Gaia museum is far less than the amount of non-contaminated concrete (around 250 m^3), crushing RCA at the demolition site would prevent unnecessary transporting of the material to the concrete producer for sorting and separation of concrete suitable for RCA production from the reinforcement and contaminated concrete, which would then be transported further to the landfill/recycling facility. Figure 3.4-4 shows the distance from the demolition site to the concrete producer is 15.7 km. Furthermore, the superfluous non-contaminated concrete and non-suitable RCA fractions could be used directly at the demolition site for other purposes.

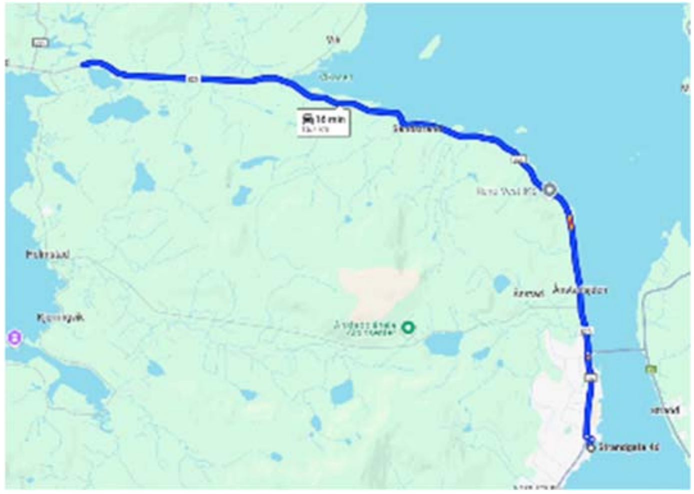


Figure 3.4-4 - Distance for the transport of RCA from the demolition site to the concrete producer.

However, the downsides of the RCA production at the demolition include the extensive amounts of dust and noise that these activities generate. The Nortura building is located closely to the city center, and it is adjacent to a town kindergarten. Hence, additional measures would have to be implemented to avoid pollution of the immediate environment, while the concrete producer allows for enough space and an isolated location that will not be affected by the adverse effects. Moreover, the concrete producer possesses enough space to ensure longer storage of the RCA, until the construction of the new Gaia museum begins.

Quality control

Aggregate is a collective term for the granular materials, such as sand, gravel, and stone, which are used as constituent materials in concrete production. Normally, 65-75% of the concrete volume is the aggregate, meaning that its properties significantly influence the quality and performance of concrete. The composition and documentation about RCA must be declared following the requirements of NS-EN 12620 [11], while for its use in concrete, NS-EN 206 [13] classifies RCA into two quality groups, AN and BN. Type AN requires a minimum of 99% of mineral content, and BN requires a minimum of 95% of the mineral content. From the Norwegian National annex for [13], up to 40% of aggregate in fraction 4/32 mm can replace the natural aggregate in the concrete mix. For the fraction 0/4 mm it is up to 20% can be replaced by RCA without further declaration (see Table 3). Higher replacement ratios can be used if this is considered in the structural design/engineering work, and the exact concrete with RCA properties are integrated.

Quality control of produced RCA for concrete production should follow the Norwegian standard NS-EN12620 [11]. This standard defines all declared properties and characteristics of the RCA. One of the main standards exclusively dedicated for RCA is the Norwegian standard NS-EN 933-11:2009 - Tests for geometrical properties of aggregates, Part 11: Classification test for the constituents of coarse recycled aggregate [14]. This standard describes constituents such as bricks, paper, plastic or tiles, which impact RCA quality. Furthermore, the limits given by [13] (see Table 3.4-3) are decisive for the production of concrete with RCA in this project. Table 3.4-3 gives the information obtained from the survey of European standards on the application of RCA in concrete. Besides the limits given in Table 3.4-3, the replacement ratio can be higher under the condition that the use of concrete with RCA is taken into account during the planning phase and additional tests are performed to certify the concrete's performance.

Table 3.4-3 - Survey of standards/regulations about RCA for concrete production in Europe

Standard	Aggregate/ Concrete type	Allowed replacement of NA by RCA [weight %]	Filler in aggregates [%]	Concrete class	Bulk density ρ_{rd} [kg/m^3]	WA [%]
NS-EN206 [12]	AN (RCA)	≤ 20% fine; ≤ 40%coarse; ≤ 40% coarse	unspecified	C25/30; C45/55	≥ 2100	< 10
	BN (RMA)	≤ 5% fine; ≤ 10% coarse;	unspecified	C25/30	≥ 2000	< 20

WA – water absorption; NA – natural aggregates.

The RCA obtained from Nortura slaughterhouse must be analyzed and CE certified prior to its utilization in concrete for the construction of the new Gaia Vesterålen museum. The RCA properties must be determined and declared according to the requirements prescribed by the Norwegian Standard.

T4.2 Testing and assessment of produced RCA

Preliminary testing took place, and it will be repeated after obtaining RCA from demolished concrete.

The RCA properties depend on parent concrete (the concrete RCA are produced from) and therefore, it is not possible to generalize their properties unless tested. In order to obtain an initial idea about the RCA properties from demolition concrete of Nortura slaughterhouse, a test RCA production was conducted from core drills used previously for the compressive strength test. A laboratory jaw crusher was used, and approximately 18.5 kg of RCA was produced. Properties such as overall particle size distribution and particle size distribution for individual fractions (0/4 mm, 4/8 mm, 8/16 mm, and 16/22 mm), water absorption, density and shape index were analyzed according to NS-EN 12620 [11]. 73.0% of fraction with particle larger than 4 mm was produced which is very favorable for utilization in concrete production. Results from other tests are in Table 3.4-2.

T3.3 Construction stage - design of Gaia museum, preparation of project for approval by authorities, demonstration of utilization of RCA in different parts of the structure

Production of new concrete types, especially those with secondary raw materials, relates to robust testing to deliver a suitable and high-quality product. Concrete with RCA is a new type of concrete, and therefore, new rules during the mix design must be followed. Such concrete has to undergo detailed testing in laboratory followed by large-scale testing at the concrete production facility. Conditions for delivery, handling, and quality control at the construction site can also vary from the traditional concrete with natural aggregates. Special attention must be given to the constituent materials, such as water/binder or water/cement ratio and admixtures, as well as the properties of fresh concrete, namely setting time and air content. Since RCA is crushed concrete, it contains natural aggregate with cement residues on its surface. This causes a higher water absorption during the mixing process, and can have negative impact on workability over longer period/open time. Furthermore, the use of admixtures like superplasticizers exclusively designed for concrete with RCA allows for better control over the workability and its maintenance over the handling period of the fresh concrete. Air content is a crucial factor closely related to freeze-thaw performance of concrete in harsh climates such as the Arctic. Since the new Gaia Vesterålen museum will be located in the Sortland harbor, and even be partially submerged in the Norwegian sea, it is paramount to produce robust and durable material.

Mix design for individual concrete types and levels of RCA replacement depends on the strength class and exposure class of the concrete. Concrete with higher replacement ratios than stated in NS-EN 206

National annex Table NA6 and NA7 [13] has to be tested and considered during the design stage. Figure 3.4-5 shows maximum amount for replacement of the natural aggregate by RCA according to the Norwegian Standard.

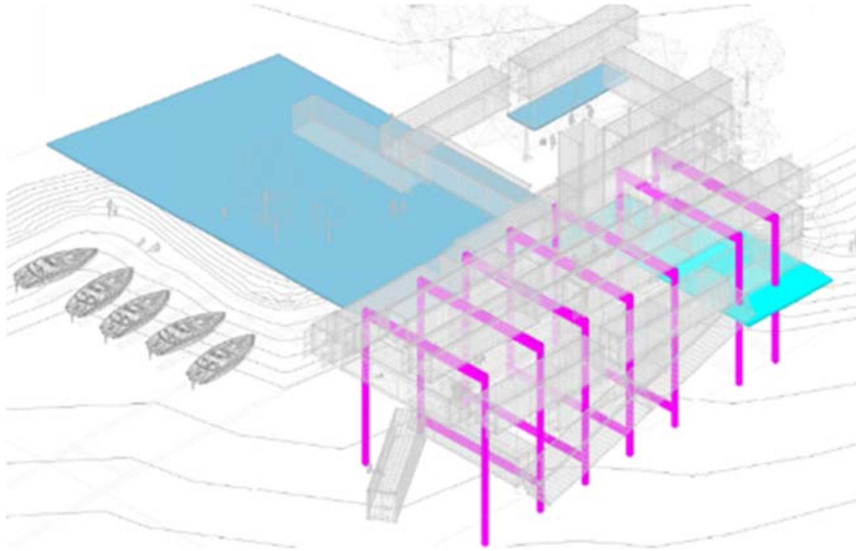


Figure 3.4-5 - Preliminary architectural design of the new Gaia Vesterålen museum made by LUA

Table : Assumed concrete types for individual structures

Volume [m3]	Assumed type of concrete	Location	Concrete type according to EN206	Exposure classes	Replacement ratio for RCA [%]
38	B45M60	floor slabs	C45/55	X0, XC1, XC2, XC3, XC4, XF1	20-100
99	B35M45	foundation plate	C45/45	XD1, XS1, XA1, XA2a, XA4b	10-40
87	B30M60	columns and beams	C30/37	X0, XC1, XC2, XC3, XC4, XF1	10-50
224	Total				

Planned concrete mixtures include one that will follow the requirements in NS-EN 206 [13] and another with a higher content of RCA than prescribed and droving present in above Figure. The targeted strength class corresponds to class B45 (C45/55 according to EN) with exposure class M60 (XC1 according to EN) and B35 (C35/45 according to EN) strength and M45 exposure class (XC4/XF1 according to EN) for the mix with lower RCA content, as well as B30 (C30/37 according to EN) with M60 exposure class for the higher RCA content mixture. The mixtures will be tested in laboratory conditions first to confirm that they can be safely used for structural concrete at the building site. Analyses will be made in the fresh state, namely consistency, air content, density and open time, and in the hardened state, compressive strength, modulus of elasticity, shrinkage, and freeze-thaw resistance. Figures above show the structural elements that will be made from concrete containing RCA. As it may be observed, the concrete with RCA will be used for structural beams and columns. Some columns will be submerged in the Norwegian sea and exposed to the sea spray. This implies that the mixtures intended for the columns must be carefully investigated and analyzed with additional tests to ensure their performance in the long term.

So far, there were two small barches of test RAC prepared with RCA produced from coredrills. Nevertheless, the quantity of RCA was so small that regular and reasonable testing of concrete properties was not possible. Therefore, optimization and testing of concrete with RCA will fully stat after the Demolition and production of RCA scheduled for 04-09. 2025.

All partners are attending regular montly meetings and contributing to progress of pilot. At this stage partner RENO seeks for bst solution for produciton of RCA. MNORD is coordinating meetigns and activiites with Sortland municipality connected to all possible permits and discussion with local politisons. UiT is planing the testing of RCA, conducted detail mapping of demoliton object and evaluated the quality of concrete, recyclability potential and assesd quantitiy of concrete in the structure. LUA intensivly work on architectural and structural design of new Gaia museum.

T4.3 Assessment of the construction of Gaia Museum with a focus on parts with integrated RCA

To be done when the construction is existing.

3.4.3 Progress according to the Pilot operational plan

List of activities (M1-M18) is given in Table 3.4-4.

Table 3.4-4 – List of activities

Tasks and activities
T1 Pilots operation plan and evaluation methodology (M1 - M31)
T1.1 Activity coordination plan for each stage
T1.2 Selection and deployment of innovative procedures
T1.3 Detailed Gantt chart development
T1.4 Evaluation methodology
T1.5 Pilot deployment plan
T1.6 Reporting
T2 Establish pilot baselines (M1-M6)
T2.1 SoA for each solution
T2.2 Establishing baselines
T2.3 Comparison between pilots
T3 Pilots deployment (M6-M42)
T3.1 Demolition stage - mapping, planning, conduction of selective demolition, sorting of CDW
T3.2 Production of RCA stage - process description and logistics
T3.3 Construction stage - design of Gaia museum, preparation of project for approval by authorities, demonstration of utilization of RCA in different parts of the structure
T3.4 Demonstration and promotion activities
T4 Pilots' technical evaluation (M12-M45)
T4.1 Summarising the efficiency of selective demolition

T4.2 Testing and assessment of produced RCA
T4.3 Assessment of the construction of Gaia Museum with a focus on parts with integrated RCA

Table 3.4-5 – List of milestones

#	Name	Month	How you know you reached it
1	Pilot Operational Plan (POP) completed	4	POP sent to WP3 leader, i.e. D3.1 Pilot deployment strategy delivered
2	Demolition of two structures	18 → 30	Selected structures are scheduled for demolition. High CDW recovery is demanded by Sortland municipality. Non-contaminated concrete is a large volume of CDW and its further processing will ensure the demand. Changed to one demolition and one repurposing of structure in order to extend live time. Demolition is delayed due to change of politic situation in Sortland municipality.
3	Available RCA	28 → 34	Up-cycling of non-contaminated concrete is supported and its processing into recycled concrete aggregates (RCA) is necessary for Pilot construction stage. Change due to delay with demolition.
5	Pilot constructed	45	The new GaiaVesterålen museum is supported by Sortland municipality and politicians. Also, there is a high demand for the public for new public spaces where people can socialize.

Three out of five KPIs for Pilot 4 given in PDS have already been achieved. First of them, socio-economic target is fulfilled as more then 300 citizens got familiar with the use of recycled and reused materials in construction and the positive impact it makes towards more sustainable communities and cities. There have been more then 20 construction companies and other industry stakeholders that visited or participated in conducted pilot phases so far. As the pilot 4 consist of 3 activities there were companies and stakeholders involved in the demolition – open tender and construction – structure design and desig of experst for example for ventilationa nad fire safety. We still need to reach out to more stakeholders and we will continue to work towards local businesses. Two scientific articles are in perparation and several articles published in local newspapers. That means that KPIs regarding the involvement has been reached.

3.4.4 Update of the operational plan

Several tasks T3.1, T3.2, T4.1 and T4.2 need prolongation period and that is marked with blue, compared to the timeline previously given in PDS, Table 3.4-6.

Table 3.4-6 – Updated timeline

Tasks and activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	2023							2024												2025												2026												2027				
	jun	jul	aug	sep	okt	nov	des	jan	feb	mar	apr	mai	jun	jul	aug	sep	okt	nov	des	jan	feb	mar	apr	mai	jun	jul	aug	sep	okt	nov	des	jan	feb	mar	apr	mai	jun	jul	aug	sep	okt	nov	des	jan	feb	mar	apr	mai
T1 Pilots operation plan and evaluation methodology (M1 - M31)																																																
T1.1 Activity coordination plan for each stage	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All																																	
T1.2 Selection and deployment of innovative procedures	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All																	
T1.3 Detailed Gantt chart development	All	All	All	All	All	All																																										
T1.4 Evaluation methodology	All	All	All	All	All	All	All	All	All	All	All																																					
T1.5 Pilot deployment plan	All	All	All	All	All	All																							All	All	All																	
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T3 Pilots deployment (M6-M42)																																																
T3.1 Demolition stage - mapping, planning, conduction of selective demolition, sorting of CDW	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno																		
T3.2 Production of RCA stage - process description and logistics																	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno														

T3.3 Construction stage - design of Gaia museum, preparation of project for approval by authorities, demonstration of utilization of RCA in different parts of the structure	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA	MNORD, LUA
T3.4 Demonstration and promotion activities	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All
T4 Pilots' technical evaluation (M12-M45)																																																
T4.1 Summarising the efficiency of selective demolition															UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno	UiT, Reno														
T4.2 Testing and assessment of produced RCA																							UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT	UiT									
T4.3 Assessment of the construction of Gaia Museum with a focus on parts with integrated RCA																																	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT	LUA, UiT

3.4.5 Lessons learnt and next steps

- A lot of work was done towards permits, planning the whole pilot and its timeline.
- Readiness level of individual partners and their full understanding of their role and responsibilities
- The timeline is challenging when the decision of local politicians is involved
- (Un)foreseen risks is the political situation in Sortland municipality
- The pilot is delayed by the local political situation, but activities are still on track with a slight delay. Successful delivery of the pilot is still realistic.
- The following 12 months will be mainly focused on demolition itself, production and testing of RCA and finalising of the new Gaia museum structural design

3.5 Implementation of the Pilot 5 – Prague

3.5.1 Summary

3.5.1.1 Objectives

The main objective of this pilot is to showcase the feasibility and benefits of using and promoting above mentioned sustainable and circular construction solutions, prove their feasibility, durability and efficiency, provide best practices and spread this knowledge and experience to professionals and society The general goal is to maximize use of recycled materials within this pilot project in combination with sustainable solutions (low carbon).

From technical point the pilot is divied to 10 technologies, shown on Table 3.5-1.

Table 3.5-1 - The list of technologies and responseable persons for their development within the pilot 5

Groups	#	Team	People
Key	0	Coordination	**R.Dvořák**, B.Slánský, M.Rabenda
	1	Rebetong structures	**P. Zelinka**, M.Havlíček, V.Hráč, J.Tichý, J.Požárek, T. Králík
	2	Rebetong mixtures	**T.Bílek**, J.Kořený, P. Zelinka
	3	Phasade from Rebetong	**B.Slánský, J.Tichý** (var. 3D tisk), P.Zelinka, M.Havlíček
	4	Urban furniture, wall-tyles	**J. Tichý**, P. Zelinka
Supplementary	5	Low carbon concrete	**V.Davidová**, T.Bílek
	6	3D printing	**J.Tichý, B. Slánský**, P.Francl, T. Bílek, M.Havlíček, V.Hráč
	7	Low carbon asphalt	**Z.Hegr**
	8	Sub-base road layers from RA	**L.Vysloužil,** Z.Hegr
Test	9	Stone dust filler	**T. Bílek**, V.Davidová, Z.Hegr
	10	Concrete slurry recycling	**V.Davidová**

3.5.1.2 General information about work done in the 1st year

M1-M4 – From the start of the project in June 2023 (M1), Pilot 5 has aimed to advance circular and sustainable solutions within residential project in Prague and its construction value chain. Key initial efforts included the demonstration of circular solution in construction industry. Main goal of Pilot 5, Skanska's "Modřanský cukrovar" residential project in Prague (Czech Republic), demonstrated Rebetong in real-world applications, focusing on both structural elements and facades (M1–M4).

M5-M7 – By December 2023 (M7), the project had made significant strides in its technical developments. Rebetong was successfully implemented. Monitoring processes with Concremote technology, led by CVUT UCEEB, were implemented to monitor essential variables such as temperature and maturity index for removing the formworks. The project also strengthened its industry partnerships, particularly for on-site 3D printing of concrete structures, with ongoing evaluations of new methods for structural and facade elements with ICE Construction s.r.o. company.

The WP7 training program was launched to disseminate these technologies, starting with workshops on low-carbon concrete and expanding awareness among construction professionals (M6–M7).

Additionally there has been organized internal workshops within the WP7 with name “art of recycling”, which focus on procedure how to handle recycle aggregate and how to change construction waste to usable building material.

M8-M10 – As of March 2024 (M10), further advancements were achieved in circular material applications by developing RebetoNG (New Generation) with higher proportion of recycled aggregate (RA) over 70%. Testing technologies including the addition of stone dust and recycled concrete slurry in mixes, reducing water use by approximately 25%.

Meanwhile, WP7 continued to train industry stakeholders, with plans to expand the program, ensuring adoption of these solutions throughout construction chains (M8–M10).

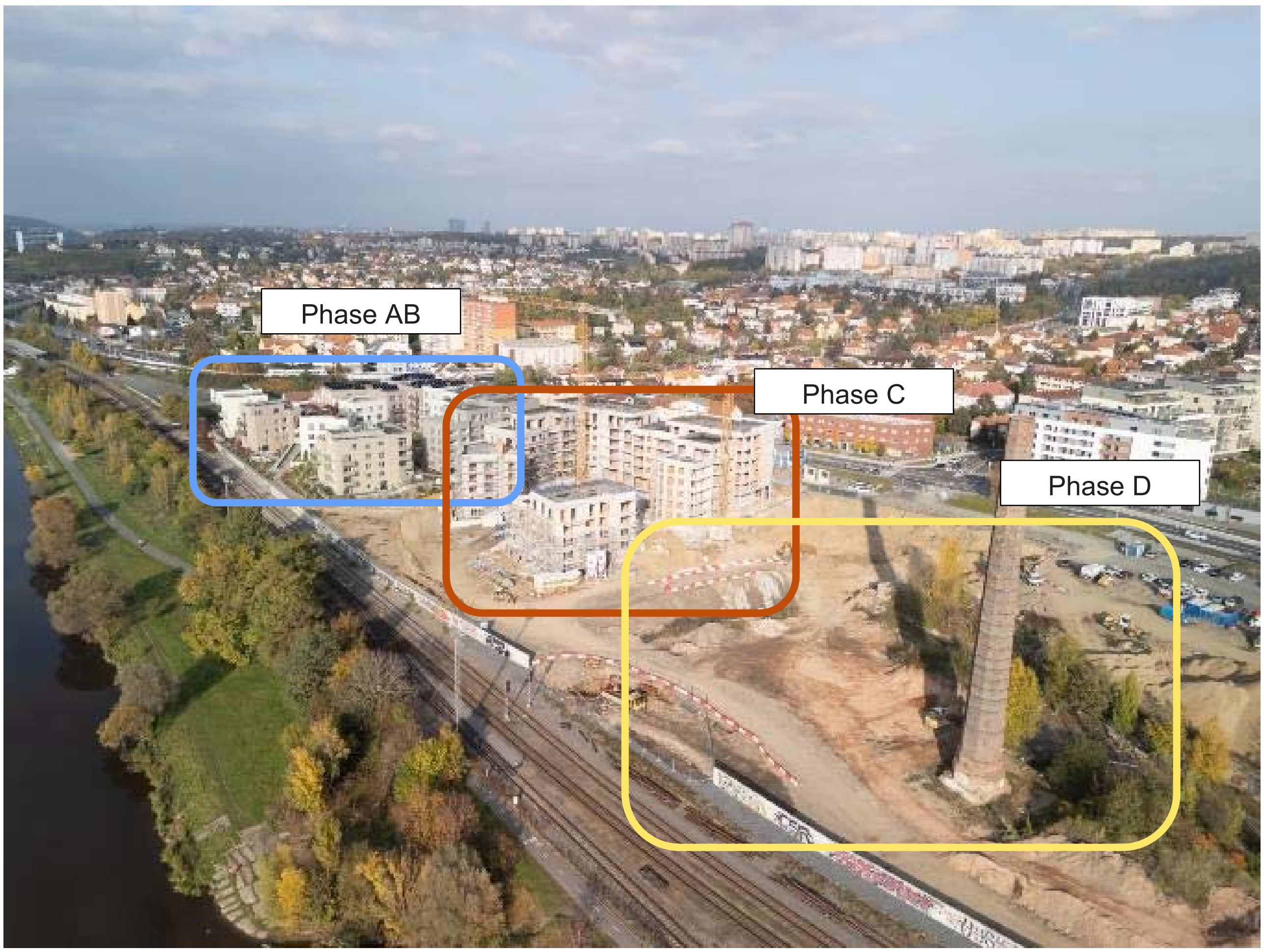

Figure 3.5-1 - Aerial view of current phase of MOCU project (24.10.2024): almost finished phase AB, phase C started in the beginning of 2024; phase D will start in 2025

M11-M12 – In June 2024 (M12), the focus shifted to preparing the upcoming general assembly in Barcelona (scheduled for M13), which will review pilot achievements and strategy adjustments. The project's budget utilization, carefully tracked from M1, indicated 49% of planned expenses for 2023 were met, aligning with Horizon 2020 standards. Preparations for the first annual report on pilot progress (D3.2) were underway, setting the foundation for CircBoost’s continued expansion and achievement of long-term circular economy goals in construction across Europe.

M13-M18 – From July to October (M13-M16) the project activities were mainly focused on finalizing development of Façade panels and their further testing on site of MOCU construction site. There are two versions of panels developed together with So Concrete a.s. and DAKO Brno s.r.o. First company is using 3d printing technology for manufacturing the façade panels, with utilization of recycled ceramic aggregate. The second company DAKO Brno s.r.o. is using technology of spraying concrete inside the molds.

Concurrently, the project began developing WP6, a marketization work package aimed at creating viable business models and engaging industry stakeholders to assess the market fit of circular solutions (M14). The production of concrete and its embedding is tightly connected with WP5 reporting, so the records of all input materials and concrete volumes are tracked through the whole construction project. These data are ale relative to the material development done in WP3, because the optimalization of utility properties for mixtures and structures goes hand-in-hand with CO2 assessment.

3.5.2 Main activities and results

- Applied optimized Rebetong® mixtures in selected structural walls and slabs (Q2–Q4 2023).
- Initiated testing of facade panels containing recycled aggregate.
- Used Concremote sensors to monitor curing and quality.
- Reused sludge water in production, replacing up to 24% of clean water.
- Participated in WP7 workshops on circular materials.
- Skanska also produced and evaluated mockups for facade and furniture elements, setting the stage for broader deployment in 2025.

T3.3 PILOTS DEPLOYMENT, M1 – M18

T3.3.1 Rebetong structures (SKA, SKA TRB, CVUT), M1-M16

From the very beginning of the project, the ordinary concrete and Rebetong mixtures were used for production of building elements and super-structure. The Rebetong was initially from its baseline used in form of single fraction mixture. For this phase an internal testing was done, which led to recommendation usage of mixtures through the whole project. As the project progressed, from M10 (March 2024), partners expanded circular material applications, with concrete mixes incorporating recycled slurry to save water and stone dust to optimize aggregate use. Notably, Skanska continued driving project goals by implementing pilot feedback into training programs and actively engaging stakeholders in workshops on circular solutions. To support ongoing technical improvements, CVUT UCEEB collaborated closely with Skanska in laboratory trials to evaluate the long-term durability of these materials, ensuring compliance with structural standards while reducing environmental impacts.

The current recommendation for usage of Rebetong mixtures is shown on Table 3.5-2

Table 3.5-2 - Internal recommendation of used recycled aggregate content for specific structures

Structure	Content of recycled aggregate	Note	Certified grades of recycled aggregate concrete according to STO
Piles	20-30 %		C 12/15 X0, C 16/20 X0,XC1-2, C 20/25 X0,XC1-2, C 25/30 X0,XC1-3, XD1-2, XC4,XF1 C 30/37 X0,XC1-3,XD1-2, XC4,XF1
Sub-base concrete	60-100%		
Horizontal structures (ceilings)	0-20%	according to the span, based on the design of the modulus of elasticity by a structural engineer	

Vertical interior structures	30-70%		
			XC4, XF1 are not produced
			Introduction of „XA1“ for C 25/30 a C 30/37

T3.3.2 Rebetong mixtures (SKA, SKA TRB, CVUT), M1-M18

From M1 (June 2023) to M18 (November 2024), the CircBoost project has focused on implementing its Pilot Deployment Strategy (PDS) across several key activities to support circular construction solutions. Initial efforts concentrated on establishing foundational technologies, such as **Rebetong**—a low-carbon concrete incorporating recycled materials—within Pilot 5 at the "Modřanský cukrovar" project in Prague. Rebetong's application extended to structural elements and facade development, aligning with the project's goal to demonstrate sustainable concrete use in real construction settings. Skanska led these efforts with technical support from CVUT UCEEB, monitoring factors like temperature and humidity through Concremote sensors to ensure structural quality and resource efficiency.

Table 3.5-3 - The type of developed mixture, their used volumes on site and recycled aggregate portion

Structure	Type of concrete	Volume (m^3)	%recycled aggregate	Note
Sub-base concrete	C 12/15 X0 S3, S4	67	69%	2 fraction Rb 0/8 + 8/16
Sub-base concrete	C 20/25 XC2 S4	63	50%	1 fraction Rb (0/16)
Foundation bellow the retention wall	C 25/30 XA1, XC2 S4	239	71%	2 fraction Rb 0/8 + 8/16
Walls	C 25/30 XC1 S4	804	71%	2 fraction Rb 0/8 + 8/16
Walls	C 30/37 XC1 S4	417	71%	2 fraction Rb 0/8 + 8/16

The role of CVUT UCEEB was focused on laboratory durability tests of mix designs and to multi-fraction testing of recycled aggregate. The test plan has been established, where a list of laboratory tests and matrix of mix designs was planned for 2023 and 2024. For fresh concrete were designed tests for Consistency at 5 min, Consistency at 90 min, Air content (fresh concrete). For hardened concrete a were designed tests based on Carbonation, Tensile strength - 4-point bending, Frost resistance - 100 cycles, and Shrinkage. Those laboratory tests were focused on Rebetong mixtures of strength grade C25/30 together with mixed cements, different portions of single and multifaction recycled aggregate.

The original goal of achieving 100% recycled aggregate (RA) use in structural concrete was intended as "up to 100%", reflecting technical feasibility rather than a fixed target. Initial tests using single-fraction RA showed promising results, but maintaining such quality in standard industrial recycling proved unrealistic. As a result, RA content dropped to as lo as 25% at the beginning of the project.

To address this, we developed new concrete mix designs using 2–3 RA fractions and blended cements (e.g., CEM II/A-M, CEM V), along with improved RA processing methods (e.g., washing). These adjustments have enabled us to increase RA content up to 75–100% in selected applications, depending on structural and exposure class requirements.

Application decisions are made in close collaboration with designers and structural engineers to ensure durability is not compromised. For example, RA concrete is now used for selected structural walls, and pilot production of facade panels with RA is underway.

Although full 100% RA use across all elements remains challenging, our ongoing on-site development is steadily increasing RA utilization. Notably, Rebetong production at the MOCU site is already above the European average (JRC 2023).

T3.3.3 Facade panels (SKA, SKA TRB), M12-M16

As M12 (June 2024) approached, preparations intensified for the upcoming general assembly in Barcelona (M13), where the project's progress would be formally reviewed. Together Skanska has received a decision, that phase D will be started early 2025. This decision has started the further development of the facade panels and the testing phase of different technologies. A mockup of façade segment has been manufactured together with selection of two companies which will be assessed as a subcontracting partner for the MCOU construction project. The Circ-Boost overlay is mainly based on supplementing the recycled aggregate and optimalization of mixture properties for the selected technology.

For the manufacturing of the panels were selected two different companies with distinctly different technology. The SO Concrete company utilize a precise 3D printing of the panels, where the final surface is at the fresh state polished by milling head. The example of such panels is illustrated on Figure 3.5-2 and Figure 3.5-3 c).

Another company is Dako Brno s.r.o. which utilize technology of sprayed concrete in the formwork. The example of such panel is shown on Figure 3.5-3 b). Both companies have produced a mockup and series of test specimens, which are assessed and compared. The elements are in the process of development, and the material used for it is in phase of durability testing and optimalization. In 2025 begin the certification process, which is required for the panels to be installed on the buildings in phase D.

Together with the development of the panels, the partner contributions played a crucial role, with Skanska coordinating pilot activities, training programs, and data-sharing initiatives that supported the execution of the project's PDS. This collaborative approach has positioned CircBoost to not only meet its initial goals but also adapt to evolving market needs, ensuring sustainable construction practices are feasible, scalable, and beneficial to industry stakeholders across Europe.

Figure 3.5-2 - Phasade panel demonstrator made by company SO Concrete a.s.: a) presentation on premise of So Concrete; b) detail of anchoring points in the panel

(a) (b) (c) (d)

Figure 3.5-3 - The installed mockup of pahsade panel on site: a) 3D render; b) Sprayed concrete specimen; c) 3D printed specimen; d) detail of anchoring to the panel

From July to October (M13 up to M16) a testing and installation of façade panels were continuing the construction site. Also the ongoing optimalization of mixture with multifaction recycled aggregate was initiated, so far with regular Portland cement. The mixtures are optimized for specific application in regard to the strength grade, environment resistance or carbon-footprint.

T3.3.4 Urban furniture, wall tiles (SKA, SKA TRB), M10-M13

For the entrance to the buildings the Rebetong tiles are being developed together with cooperation with company Cidemat Hranice. The technology is based on two layers concrete with low and high water cement ratio, using vibro-compacting technology. For the face layer a rebetong mixture optimized for vibro-compacting is used. The surface of tiles are afterwards polished using standard procedure for concrete tiles. There are two surface treatments being used for a letter negative relief in the tiles. The example of test specimen is shown on Figure 3.5-4.

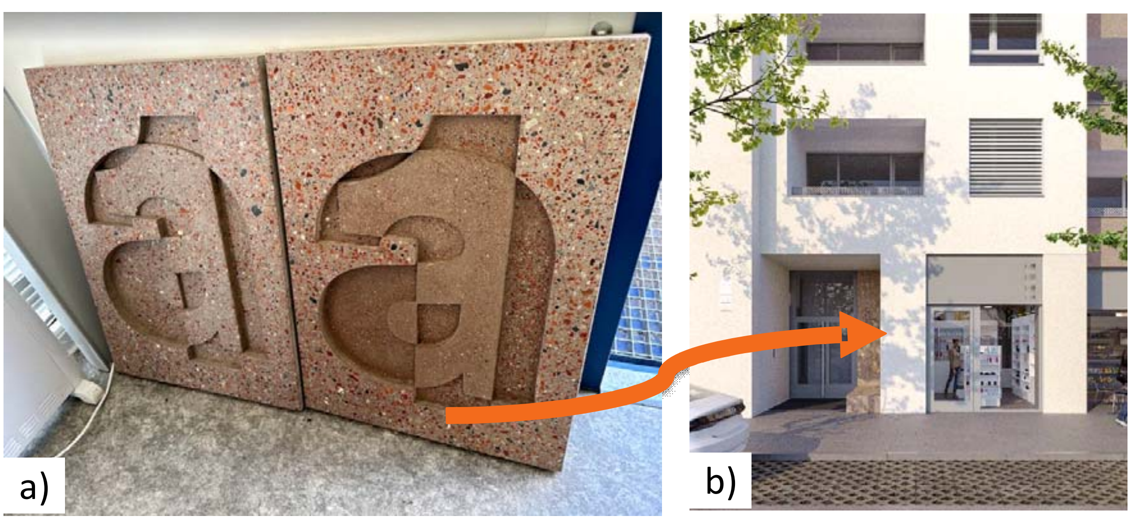

Figure 3.5-4 - Prepared test sample of Rebetong polished tile, for the entrance of building a1: a) Polished tile manufactured by Cidemat Hranice; b) Image from visualization of project

T3.3.5 Low carbon concrete (SKA, SKA TRB, CVUT), M7-M18

By M7(December 2023), the project achieved significant milestones in material testing and circular applications. Besides Rebetong, urban furniture prototypes and road layers were successfully constructed from recycled aggregates. Collaborative efforts with industry partners such as ICE Industrial Services enabled on-site 3D printing, pushing the boundaries of sustainable construction techniques. These activities also benefitted from contributions by Skanska, who organized WP7 training workshops aimed at upskilling construction teams on low-carbon materials and circular economy principles.

The primary challenge in reducing the carbon footprint of these mixtures lies in the use of cement. Recycled aggregate contributes only marginally to carbon footprint reduction; a more significant impact can be achieved by utilizing blended cements. The current carbon reduction is demonstrated in Table 3.5-4.

Table 3.5-4 - Comparision of effect of different mixed binders on reduction of carbon footprint

Type of binder	CEM I	CEM II AM	CEM II BS	CEM III	CEM V
Object AB [m3]	0	370	90	6	890
Object C [m3]	0	2900	10	130	610
CO^2 Reduction [%]	0	8%	15%	50%	20%

T3.3.6 3D printing elements (SKA, SKA TRB), M6-M9

Skanska, in cooperation with ICE Industrial Services, implemented 3D printing in the MOCU project residential area. A robotic 3D printer was temporarily installed on the fourth floor of the shared community terrace, where it printed an atypical sanitary room out of concrete within two hours. The material for the 3D printing was prepared from local raw materials and reaches a strength class of C30/37 or higher.

a) b)

Figure 3.5-5 - 3D printing process on site together with cooperation with ICE Construction company: a) Actual printing in protective tent on the roof of building AB; d) final print resting in protective tent

In addition to speeding up the construction process and increasing project efficiency, 3D printing also offers another tool for achieving more sustainable construction. The technology enables the use of special printable materials that are environmentally friendly and recyclable. This minimizes the negative impact on the environment. In addition, 3D printing can also be beneficial from a circular economy perspective, as in some cases recycled construction waste such as plastics, bricks, concrete, mortar, plaster, etc. can also be processed. It also helps to address labour shortages and offers an opportunity for the digitalisation of the construction industry. The illustration of printing process is shown on Figure 3.5-5

T3.3.7 Usage of asphalt with reduced CO2 footprint (SKA), % of fulfillment: 0%
This technology has not yet started its execution phase.

T3.3.8 Sub-base road layers from RA (SKA), % of fulfillment: 0%
This technology has not yet started its execution phase.

T3.3.9 Usage and testing of secondary raw materials in concrete (SKA TRB), M1-M9

To adjust rheology, different admixtures can be used, such as plasticizers or superplasticizers, which primarily work by reducing water content. Another approach involves optimizing the granulometric curve, where fine inert fillers can be utilized. In the MOCU project, an admixture of stone dust was tested during months M1–M9 of the project. A total of 100 m³ of concrete containing this admixture was produced, with a relatively small dosage of 20.4 kg/m³. The optimization of the dosage yielded good results; however, the availability of this material is too limited for large-scale use. Since it is a secondary raw material, the transportation costs of moving the stone dust from distant producers to the concrete plant are economically unviable. Additionally, the CO_2 footprint increases with every extra kilometer, and the impact on rheology is not significant enough to justify these disadvantages. For these reasons, we plan to discontinue further development of this technology.

From this point of view, the mixtures are under control in terms of set KPIs and all key factors are met. The most important indicator is portion of used recycled aggregate (KPI 1 and 2). The Table 3.5-5 has KPIs for all the used technologies within the Pilot 5, and it is notable, that some of the technologies already fulfilled their targets. Other technologies hasn't yet started and are planned for later application on the project (KPI 3,4,7,8 and 9). Also from the initial tests we have observed that the production of stone dust within the KPI 9 and test technology 9. At the initial POP this technology was mentioned, and as the development went further, we have realised that the overall production of stone dust is not that high and better utilization of the stone dust is in agricultural production. The stone dust was mainly used as an inert admixture to tackle the workability as a fine compound of aggregate granulometry curve. We have concluded that the current stone dust is a by-product and don't reach the quantities, that would allow us to utilize it effectively on the project. For this practical reason, we would like to remove this technology from the list.

T3.3.10 Usage of cement slurry in Rebetong (SKA), M7-M16

In the MOCU project, concrete and Rebetong are supplied from the Chodov concrete plan (Skanska Transbeton), which is closest to the construction site. The plant is equipped with a STETTER RA 20 residual concrete recycling system and can operate in winter conditions down to -10°C, thanks to heated mixing water and a tempered aggregate storage tank. This technology processes leftover concrete by separating washed aggregate and cement-rich slurry water. The aggregate can be reused in production, while the slurry water is typically stored in slurry lagoons. As part of the MOCU project, the recycling of cement-rich slurry water is being tested for use for regular concrete. The addition of slurry water is reducing the workability of concrete, which case of regular concrete is not a problem, but for Rebetong it can be challenging thanks to recycled aggregate.

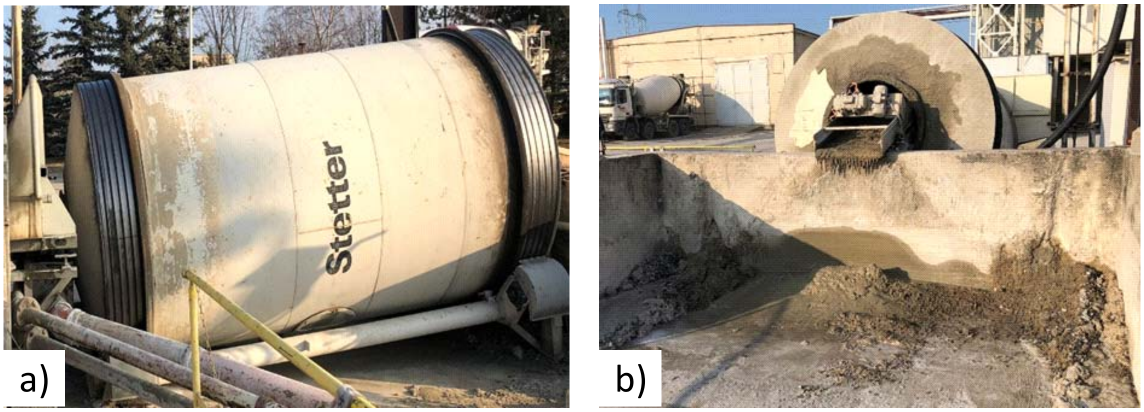

Figure 3.5-6 - Recycling system STETTER RA 20 for recycling the remaining concrete

The slurry water contains a high concentration of still-active cement particles, which can be used as a partial replacement for mix water in regular concrete. So far, slurry water has been used to replace up to 23% of clean mix water for Building AB and 24% for Building C.

3.5.3 Progress according to the Pilot operational plan

From the point of view of KPIs we are tracking the concrete production on Modřanský Cukrovar, and periodically updating the list of all delivered mixtures, their mix designs and properties. The main suplier of concrete on the project is Skanska Transbeton, thus we have control over the production. The development of the mixtures is in close collaboration with UCEEB under the Prague university of technology.

From this point of view, the mixtures are under control in terms of set KPIs and all key factors are met. The most important indicator is portion of used recycled aggregate (KPI 1 and 2). The Table 3.5-5 has KPIs for all the used technologies within the Pilot 5, and it is notable, that some of the technologies already fulfilled their targets. Other technologies hasn’t yet started and are planned for later application on the project (KPI 3, 4, 7, 8 and 9). Initial tests for KPI 9 and test technology 9 have shown that stone dust production is lower than anticipated. During the initial project operational plan (POP), this technology was included. However, as the project progressed, we realized that the total stone dust production is insufficient for effective use within the project. Instead, stone dust has been identified as more suitable for agricultural applications.

Previously, stone dust was primarily used as an inert admixture to improve workability, serving as a fine component in the aggregate granulometry curve. Given its limited quantities and lack of project relevance, we have concluded that this technology is impractical and recommend removing it from the list.

Table 3.5-5 - List of set key-performace indicators (KPI) within the pilot 5 and their current status

#	Technology	Technical KPI 1	Goal value 1	Currently 1	Technical KPI 2	Goal value 2	Currently 2
1	Rebetong structures	Percentage of structures made of RAC	> 20%	21%	Volume of RAC used for structural elements (walls, subbase concrete,…)	> 1000 m3	NA: 7339 RAC:1516
2	Rebetong mixtures	Avarege ratio of replacement of NA by RA in RAC	> 30%	49%	Use of RA for project	> 500 t	RA: 720t NA: 1024t
3	Facade from Rebetong	Average ratio of replacment of NA by RA	> 20%	N/A yet	Volume of facade elements with use of RAC	> 1000 m2	N/A yet
4	Urban furniture, wall tiles	Average ratio of replacment of NA by RA	> 30%	N/A yet	Volume of wall tyles and furniture with use of RAC	> 20 m3	N/A yet
5	Low carbon concrete	CO2 reduction for L-CC applications compare to benchmark (CEM I)	> 15 %	19%	Volume of L-CC appliactions	> 1000 m3	5006
6	3D concrete printing	Number of on-site pilot 3DCC	1	1			
7	Low carbon asphalt	Ratio of RAP in asphalt mixture in selected applications	> 30%	N/A yet	Volume of low carbon asphalt mixtures	> 100 t	N/A yet
8	Sub-base road layers from RA	Avarege ratio of replacement of NA by RA in sub-base layers	> 30%	N/A yet	Volume of sub-base layers with RA	> 100 t	N/A yet
9	Stone dust filler for concrete	Ratio of stone dust to cement	> 10%	N/A yet	Number of pilot test sections	1	N/A yet
10	Concrete slurry recycling	Reduction of used clean water	> 10%	31%	Number of pilot test sections	1	2

Explanation for each KPI:

Tech KPI 1.1 Percentage of structures made of RAC is ratio of total sum Rebetong concrete with recycled aggregate $\sum V_{RAC}$ of ordinary concrete with natural aggregate $\sum V_{NAC}$, the equation is then:

$$\text{Tech KPI 1.1} = \frac{\sum V_{RAC}}{\sum V_{NAC}} \cdot 100\%$$

Tech KPI 1.2 Avarege ratio of replacement of NA by RA in RAC is a mean ratio of recycled aggregate RA to natural aggregate NA within the RAC mixtures among all batches supplied on Pilot 5. This equation will be also used for Tech KPI 1.3 and 1.4:

$$\text{Tech KPI 1.2} = \frac{\sum_{i=1}^{N} RA_i}{\sum_{i=1}^{N} (RA_i + NA_i)} \cdot 100\%$$

Tech KPI 1.5 CO2 reduction for L-CC applications compare to benchmark (CEM I) is ratio of difference between total emission of kg CO2 in concrete mixtures with E_{CEMI} (CEM I 42.5 R) and used mixtures with blended cements E_{LCC} (CEM V, CEM II AM):

$$\text{Tech KPI 1.6} = \left(\frac{E_{\text{CEM I}} - E_{\text{LCC}}}{E_{\text{CEM I}}}\right) \cdot 100\%$$

Tech KPI 1.6 Number of on-site pilot 3DCC is simply count of 3D printing applications on pilot. Because the printing requires the transport of specialized machinery and preparation it is easily distinguishable and the KPI doesn't need any complex equation.

Tech KPI 1.7-1.9 use the same principle as in the Tech KPI 1.2.

Tech KPI 1.10 Reduction of used clean water is based on the concrete plant consumption of clear ald sludge water which is used on regular basis. The KPI is simply ratio between the weight of total clean water and sludge water used in project so far.

$$\text{Tech KPI 1.10} = R_W = \frac{W_{\text{clean}}}{W_{\text{sludge}}}$$

Tech KPI 2.1 Volume of RAC used for structural elements (walls, subbase concrete,…) is measuring the total volume of concrete with recycled aggregate and total sum of concrete with natural aggregate only.

Tech KPI 2.2 Use of RA for project is sum of all recycled aggregate and natural aggregate used on the project.

Tech KPI 2.3 Volume of facade elements with use of RAC is sum of volume of RAC used for production of Phasade panels.

Tech KPI 2.4 Volume of wall tyles and furniture with use of RAC is sum of volume of RAC used for production of RAC tiles and urban furniture.

Tech KPI 2.5 Volume of L-CC applications is sum of volume of RAC with blended cement (CEM II AM, CEM II BS, CEM III, CEM V) used on project.

Tech KPI 2.7 Volume of low carbon asphalt mixtures is sum of volume of asphalt mixtures with lower CO_2 used on project.

Tech KPI 2.8 Volume of sub-base layers with RA is sum of RA used for sub-base layers.

Tech KPI 2.9 Number of pilot test sections corresponds to test sections with low-carbon asphalt mixtures.

Tech KPI 2.10 Number of pilot test sections corresponds to test sections with recycled aggregate sub-base layers.

3.5.4 Update of the operational plan

In the pilot operational plan a several phases of the developer project itself were presented:

i) Phase AB – realization dates 2022-2024
ii) Phase C – realization dates 2023-2025
iii) Phase D – realization dates 2024-2026
iv) Phase E – realization dates 2025-2027
v) Phase F – realization dates 2026-2028
vi) Phase G – realization dates 2027-2029

From this the phase D started in Q1/Q2 2024, which was earlier then expected. Because of this we propose to move milestone 2 and 3 later in the year 2025, to fully utilize development of low-carbon concrete together with multi fraction of recycled aggregate. Both milestones 2 and 3 should be therefore moved to the M27.

Based on the POP there were set list of both milestones and KPIs which were tracked during the first etap of pilot. The milestones were selected based on the estimation of development of both technologies and the developer project itself. Because the stage C and D has started sooner than the initial estimation, the milestones should be moved in later months in 2025. For that reason also the work on Low-Carbon Rebetong and RebetoNG with multi-fraction of recycled aggregate started sooner. So associate partner Skanska Transbeton is able together with Prague university of Technology push further both technologies. To do this we propose to move the milestone 2 and 3 later in the year 2025 to the month 27 of Circ-Boost (08/2025),Table 3.5-6.

Table 3.5-6 - List of miletones from PDS with proposal of prolonging the milestones 2 and 3

#	Name	Month	How you know you reached it
1	Pilot deployment strategy completed	6	Pilot deployment strategy delivered to and approved by WP3 leader
2	RAC mixtures optimalization	20 → 27	Rebetong mixtures are optimized with final successful testing
3	Structural elements from RAC	24 → 27	Rebetong is successfully used for structural elements
4	Installation of facade panels on site	40	Facade panels are certified and installed on building
5	Urban furniture installation	36	The designed elements are installed on the project
6	Cost and emission study	46	Cost and emission report

We have also concluded that technology 9 should be removed from the list. In the Skanska Transbeton s.r.o. there is simply not enough of this material to be effectively used in development.

Achievements

- New mix designs completed and tested
- Structural application of Rebetong in pilot zones
- Sludge water reuse documented
- Mockups of facade panels fabricated
- Use of sensors for curing control

RP2 Plans:

- Broader application across the site
- Certification and structural validation of panels
- Usage of LCC asphalt mixtures and sub-base layers
- Finalization of training materials and exploitation plan

Delays:

- Milestone 2 RAC mixtures optimalization moved from 20 → 27 month
- Milestone 3 Structural elements from RAC moved from 24 → 27 month

3.5.5 Lessons learnt and next steps

In the next phase of the project, the focus will shift to the development of low-carbon concrete incorporating recycled aggregates, alongside the advancement of façade panels. These two streams will form the core topics of the upcoming phase, with collaboration from the UCEEB Institute under the Prague University of Technology on laboratory testing.

The façade panels will be subjected to real-world environmental exposure, with full-size specimens already placed on the construction site. The primary focus will be on evaluating the durability of the exposed surfaces under freeze-thaw cycles, carbonation, and aesthetic considerations from an architectural perspective.

Aesthetics play a significant role in material selection, often requiring a balance between visual appeal and performance characteristics. This constraint means that the material with the highest resistance may not always meet aesthetic requirements. Insights gained from this phase will contribute to the development of a certification process for the panels, ensuring they can be safely installed on buildings.In next phase of project a focus on development of low-carbon concrte with recycled agregtae will be placed together with phasade panels.Those three streams will be main topic in next phase, and cooperation with UCEEB institue under the Prague University of Technology will cooperate on the labroatory testing. The phasade panels will be exposed to the surounding enviroment and there are already a full-size specimens placed on the construction site. The main focus will be on testing the durability of exposed surface to the freeze-thaw cycles, carbonatation and also the estetics from the point of view of architects. The aestetics influence the used materials, which may have different qualitative parameters, which means, that the material with best possible resistance cant be picked if it fullfill also the aestetics parametrs. This will be sub-sequently used for developing a certification process of the panels, so they can be safely installed on the building.

4 Conclusion

During the first year of the pilots project implementation, preparatory work - protocols, designs, digital platform development, application for permits and in some cases application of innovation - has been done. The plan developed in the Pilot Delployment Strategy (direction, goals, activities, KPIs, among others) was followed.

In large part, the work of the WP3 was successful, in the sense that pilots have achieved progress according to plan and several of them have proved a valuable technical test. A potential risk to implementation and potential deviations from the proposed timeline stems from administrative delays in obtaining construction and deconstruction permits, which are critical milestones for subsequent activities related to recycling processes. This is a common challenge for all pilot projects implemented in real-world environments, such as construction sites, and reflects a typical situation in construction practice. However, mitigation measures have been foreseen which will allow completion of all pilots by M42 as planned in PDS.

There was a successful interaction with other WPs, especially with WP2, WP7 and WP8. Established communnication channels and targeted key steakholders (WP2) would be of crucial importance for achieving the overall success of the project – an uptake of innovative solutions developed through the work of pilots. Through the interactions with WP8, pilots provided a lot of data for dissemination. Visibility of results and activities has been successfuly improved. Two training sessions were successfully organized and conducted, receiving high marks in the evaluation process.

In the second year of the project, the pilots will continue with implementation of updated plans. Activities will be focused on full-scale deployment of innovative solutions such as non-structural application of recycled or reused materials and deployment of physical platform. Adopted and updated evaluation methodology will be applied in order to asees the technical improvement of each solution. Comparison with KPIs and baselines will be performed.

Continuing closer collaboration with the other WPs is necessary to ensure that the WPs contribute as much as possible to the overall objectives of the project. Collaboration with WP5 –Evaluate and WP6 – Marketize will bring additional value to pilots outcomes.

ANNEX 1

University Gustave Eiffel
Report year 1 - 2024

MS27 - Axe 1: Characterization of materials and ways of reuse - Milestone 1

Operational analysis of construction waste recycling platforms

Co-funded by the European Union

Document Information

Grant Agreement Number		101082068	Acronym	CIRC-BOOST
Full Title	Operational analysis of construction waste recycling platforms			
Lead Beneficiary				
Responsible Author	Duc Myriam, Leguen Lauredan			
Contributions From				

Document History

Version	Issue Date	Internship	Description	Contributor
Version1	27/11/2024		Final report	Duc Myriam, Leguen Lauredan
Version2	04/04/2025		Final report translated in English	Duc Myriam, Leguen Lauredan

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Table of Contents

Table of Figures Tables

List of abbreviations

BTP: Building and civil engineering

TP: Public Works

ICPE: Installation Classified for Environmental Protection

LTECV: Law on Ecological Transition and Green Growth

AGEC: Anti-Waste and Circular Economy

EPR: Extended Producer Responsibility

PEMD: Deconstruction Products, Equipment and Materials

CSTB: Centre Scientifique et Technique du Bâtiment (Scientific and Technical Building Centre)

ADEME: Agence De l'Environnement et de la Maitrise de l'Energie (French Environment and Energy Management Agency)

CEREMA: Centre d'Etudes et d'Expertises sur les Risques, la mobilité et l'Aménagement (Centre for studies and expertise on risks, mobility and planning)

DREAL: Direction Régionale de l'Environnement de l'Aménagement et du Logement (Regional Department for the Environment, Planning and Housing)

DRIEAT: Direction Régionale et Interdépartementale de l'Environnement, de l'Aménagement et des Transports d'Ile de France (Ile de France Regional and Interdepartmental Department for the Environment, Planning and Transport)

DDT: Direction des Départements Territoriales (Departmental Territorial Management)

UT: Union territoriale

PRPGD: Plan Régional de Prévention et de Gestion des Déchets (Regional Waste Prevention and Management Plan)

FNTP: Fédération Nationale des Travaux Publics

SEDDRE: Syndicat des Entreprises de Déconstruction, Dépollution et Recyclage (Association of Deconstruction, Pollution Control and Recycling Companies)

FFB: French Building Federation

Executive summary

This report covers the operational analysis of building and civil engineering waste as part of the European CIRCBOOST project. The aim is to understand the mechanisms involved in the management and recovery of construction waste in recycling platforms, a major challenge for the circular economy and environmental protection. Due to their volume and diversity, the management of these wastes requires a number of specific strategies and regulations to maximize recycling and meet European and national targets. This study examines the regulatory framework governing construction waste management at both European and French levels, and the transposition of European frameworks into French law. It also looks at the contribution made by the various players in the construction and public works sector to the implementation of these laws and the increase in recycling in France.

In order to gain a clearer picture of the recycling field, a campaign of visits to recycling platforms was carried out, and the platforms visited were: YAM, EIFFAGE, YPREMA, CEMEX, ECOSELECT, WIAM. These platform visits enabled us to carry out a study of operational processes within the recycling platforms. In addition, a mapping analysis was carried out to gain an overview of the coverage of recycling platforms in relation to demolition and construction zones in the Ile-de-France region. This study enabled us to assess the proximity of the platforms to the construction zones, as well as their supplies.

Keywords

Construction demolition waste (CDW), inert waste, recycling platform, demolition, construction, reuse, recycled materials, recovery, stakeholders, recycling process, waste storage.

1. Introduction

1.1 CIRCBOOST project background

Construction and demolition waste is one of Europe's largest waste streams (Moschen-Schimek et al, 2023). In 2018, the total waste generated in the EU, all economic activities and households combined, was 2.3 Mt, 36% of which came from the construction sector. Including waste from mines and quarries, almost two-thirds (1.5 Mt) of the total waste generated was major mineral waste (EUROSTAT, 2020b). In France, construction waste accounts for ¾ of the 294 million tonnes of waste generated (i.e. 74%), 92% of which is inert waste. Moreover, of inert waste, 31% is recycled, 39% is used as quarry backfill, 6% is used in another development or construction project and 24% is not recycled, not recovered and not reused, and is therefore sent to ISDI-type landfill (CERC, 2018).

Against this backdrop, the European Union has launched the CIRCBOOST project - Boost the Future Of Construction- Boosting the uptake of circular integrated solutions in construction value chains (https://circboostproject.eu/) as part of the Horizon Europe program. This project brings together 5 pilot experiments in 5 countries. The pilot developed in France aims set up a digital platform to develop interoperability between existing platforms and optimize the matching of supply and demand in the field of **re-use**[1] of equipment and products (e.g. sanitaryware, cable trays and pipes, lighting, ceiling panels, wood, bricks and structural elements, kerbstones and paving stones, etc.) and to set up a **recycling** platform (mainly concrete gravel) to recover construction and public works waste. As part of this project, recycling platforms play an essential role in increasing the recovery of construction and public works waste. They should contribute to resolving the supply and demand for materials, encourage the use of alternative and sustainable construction methods, and facilitate the use of second-hand materials from deconstruction operations for new structural applications.

The physical platform developed in CIRCBOOST will enable inert waste to be recycled into reusable materials, thus reducing the amount of waste sent to landfill sites. This type of platform, which takes many forms, is generally regulated by laws and decrees, which reinforces their importance and helps to achieve the reuse and recycling targets imposed by Europe and the French state, as they enable visible and quantifiable flows to be tracked (unlike on-site recycling and materials that escape traceability and end up in unauthorized landfill sites). In the South-East region, for example, in 2018, around 1.69 Mt of inert waste from construction and public works, i.e. 9% of inert waste produced, was disposed of and stored illegally (not negligible). (ORDEC- Déchets de chantier, 2019)

It should be noted that waste traceability is an important point for monitoring and assessing the impact of decisions and new strategies on the evolution of a sector (numerous biases or evaluation methods and counting perimeters). However, the figures presented must always be treated with great caution. What's more, studies are always fairly long - at least 2 years - which prevents day-to-day management.

[1] Reuse : def recycling : def .... Waste pyramid

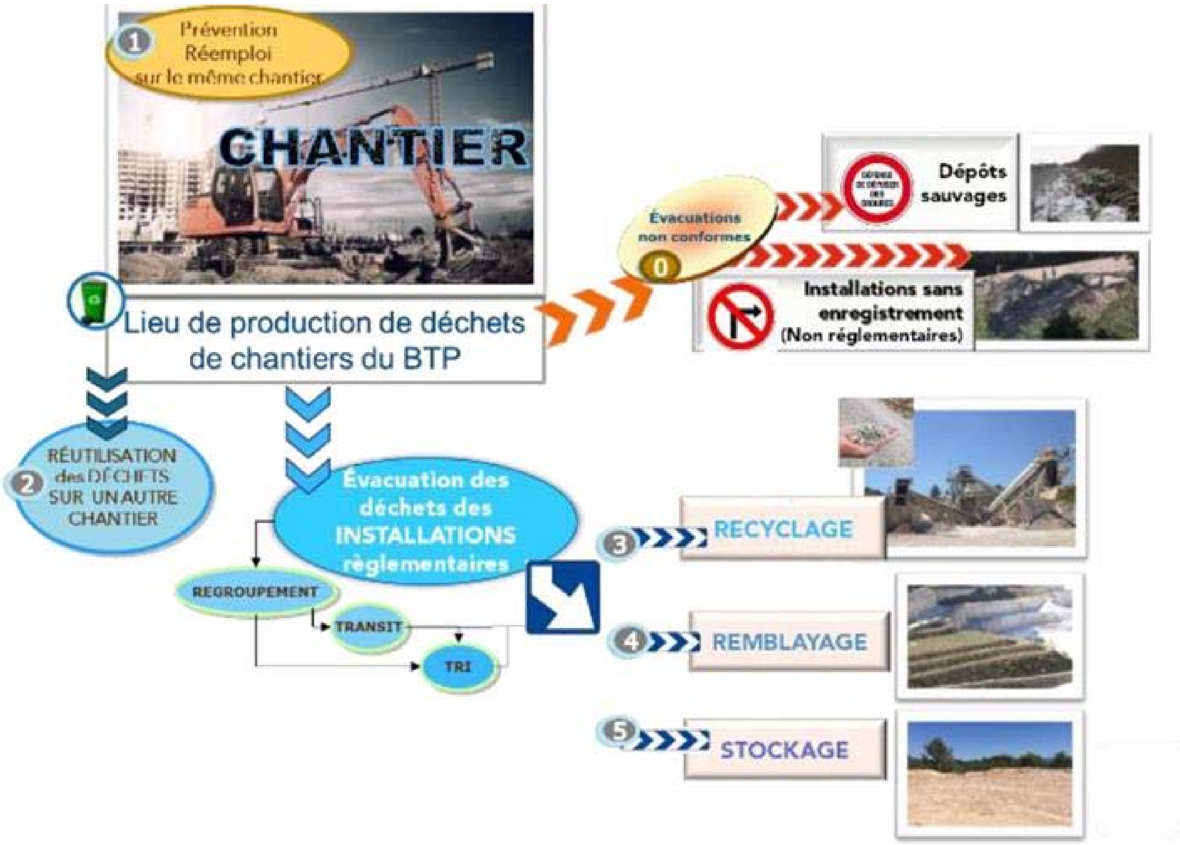


Figure1 general diagram of inert waste flows from construction sites and their treatment channels (Déchets de chantiers du BTP-ORDEEC, 2019)

1.2 Objectives

This report focuses on the operational analysis of existing recycling platforms in terms of efficiency, operation and processes, as well as economic profitability and environmental impact. The regulatory framework for construction and public works waste management is reviewed, together with the European and French regulatory framework, in order to understand European regulations and their transposition into French law. An in-depth analysis of construction waste recycling platforms in France is carried out to establish their typology and better understand what impacts their configuration. Indeed, each platform is specific in terms of the type of company that owns it (earthworker, builder, cement manufacturer...), its surface area (constrained land in an urban environment), its location (presence of a quarry), and nearby means of transport. This work is being carried out in parallel with the implementation of the new recycling platform planned in an urban environment in the Paris region as part of the CIRCBOOST project (action supported by Eiffage).

The questions to which this report provides answers are as follows:

- Who are the major players in the management of construction and demolition waste (CDW)
- What different forms can platforms take? With these factors in mind, will it be possible to develop and improve a high-performance, cost-effective and environmentally-friendly platform for recycling construction waste in an urban environment, while complying with current regulations?
- What parameters determine whether a platform takes one form or another?

- What are the avenues for improvement or research in conjunction with the platforms to increase the value of CDW?
- What is the current state of play regarding the inventory of platforms and their location in relation to material and demolition zone requirements?

To answer these questions, a bibliographical synthesis based on scientific literature was carried out to establish the regulatory framework. This was followed by a series of visits to recycling platforms

This report presents :

- 1st Part: The European and French regulatory framework for waste management.
- 2th Part: Analysis of construction waste recycling platforms: highly variable configurations.
- 3(rd) Part: Typology analysis and platform mapping.
- Part 4: Suggested improvements and recommendations.

1.3 Methodology

The operational analysis of construction waste recycling platforms is based on a multi-disciplinary methodology, combining bibliographical research, interviews with platform managers and on-site visits to the facilities.

My work consisted in designing **an** in-depth **questionnaire sheet** to collect precise data from recycling platforms. The sheet is divided into sections covering: Administrative data such as location, opening date, number of employees and legal status;

- Economic data such as land costs, sales prices for recycled materials, energy consumption and waste reception rates;
- Operational data detailing waste sorting and treatment processes, as well as material flows;
- Technical data on equipment used and recycling technologies;
- Finally, regulatory data, such as compliance with environmental standards and regulatory difficulties encountered.

Once the questionnaire had been drawn up, interviews were held with the heads of the recycling platforms. These interviews provided detailed information on the operation of the platforms, waste sorting and processing methods, and future prospects. The approach was rounded off by visits to waste recycling platforms. Thanks to this on-site experience, it was possible to observe the various stages of recycling at close quarters, to visualize the equipment used, to grasp the flow of materials and waste, and to exchange views with operators in the field.

The analysis was enriched by these observations, which provided field data and enabled us to compare hypotheses and theories with reality on the ground. Indeed, while the theory of recycling may seem simple on paper, it is often difficult to understand the brakes and levers to be used, without a confrontation with on-site activities. The obvious quickly becomes apparent.

Choice of study area and platforms visited

The main activities of the recycling platforms we visited vary, and spread across the Ile de France and Brittany regions (geographical accessibility). Some are linked to CIRCBOOST project collaborators (with the presence of EIFFAGE and NGE). This has facilitated access to installations and fostered close collaboration with managers and operators in the field. This partnership gives us privileged access to the information we need to carry out the study. A confidentiality agreement should be signed for access to more confidential data on material flows and platform operation/costs.

2. Bibliography and summary of the regulatory framework for waste management in France

The management of construction and public works waste is governed by a set of regulations designed to ensure efficient, environmentally-friendly ~~and economically viable~~ management

To understand the structure of the regulatory framework in France, it is essential to classify the various legislative and regulatory texts in a hierarchical manner.

Although the **Environment Code** is an important foundation, it includes articles and laws derived from European directives adopted since 1975. Indeed, European directives set targets to be achieved by Member States, forming the basis of regulations concerning construction waste management. Subsequently, these **directives** are translated into French law by laws that define the conditions for achieving the European objectives. The **implementing decrees** set out the specific procedures and responsibilities for the parties involved, specifying the practical instructions of these laws.

In addition, the **decrees** specify in greater detail the practical obligations that establish technical standards and compliance criteria for the various stages of waste management. Thanks to this classification, it is possible to grasp how the different levels of regulation are organized and how they influence waste management in France.

2.1 Legislative definition of construction waste

According to article L.541-1-1 of the French Environment Code, waste is defined as any substance or object, or simply any movable asset, which the holder discards or intends or is obliged to discard. Construction and public works waste encompasses all waste produced on building sites and resulting from public works and construction. It can come from building construction (excluding demolition), public works (construction and modification, maintenance and deconstruction of roads, networks, etc.) and building demolition.

Figure2 shows how waste and materials from construction sites are distributed by type of site. As a percentage of the total volume of waste and materials before reuse

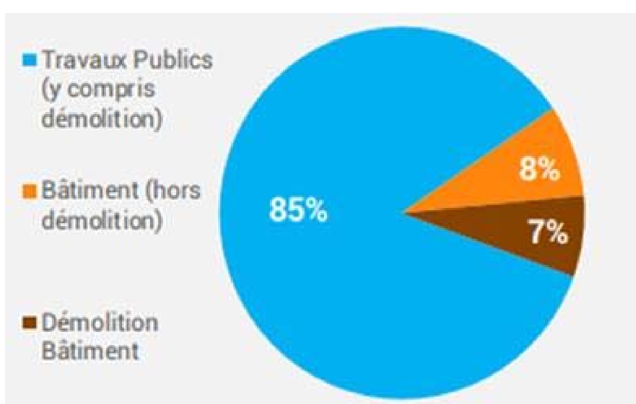


Figure2 Distribution of building and public works waste deposits by construction site expressed as a percentage of total tonnage of waste and materials before reuse (source Réseau des CERC, diagnostics départementaux Déchets et Recyclage du bâtiment et des travaux publics entre 2010 et 2015 - CERC 2018)

This graph is based on data from the CERC network, which carried out studies on building and public works waste and recycling from 2010 to 2015 in 71 départements.

The main source of waste in the building and public works sector remains public works, including demolition, which accounts for 85% of the total. 8% of waste comes from construction (excluding demolition), while 7% is generated by building demolition.

Public works account for the majority of construction waste production, given that road and rail infrastructure construction work involves moving/excavating large quantities of inert materials. A case in point is the Grand Paris Express project, which generated 47 million tonnes of excavated material during the digging of the tunnel boring machines and construction of the stations for the future Ile de France transport network (Schéma de gestion et de valorisation des déchets du grand Paris Express, 2022).

At this level, we need to distinguish between materials from public works (mainly soil) and materials from buildings (concrete, stone and a wide variety of other materials). While large-scale linear projects (freeways and railroads) allow for almost complete reuse of soil on site, projects in urban areas require excavation and transportation of soil (often polluted) away from the site. This soil is used to create embankments, berms and landscaping when the opportunity arises (there aren't enough of them at present to absorb the large quantities of soil), but it is mainly used to backfill quarries or to be stored in suitable landfill sites (e.g. ISDI). Structural building materials are most often transformed into aggregates such as concrete gravel, after meticulous sorting to separate out the plaster. Similarly, bituminous pavement cuttings are reintroduced for the most part into pavements, or end up as mixed gravel on construction waste management platforms. In the case of buildings, attempts are currently being made to reuse concrete structures without the need for crushing. This type of management should be facilitated by eco-design, which is developing with modular, demountable structures. As for equipment in buildings, this requires extensive selective deconstruction, and often handling and reconditioning, which makes the work of the deconstructors who replace the demolishers a complex one.

Reuse and repurposing are trying to develop simultaneously to become common practice, enabling renovation and construction work to reduce the amount of waste generated by the renewal and transformation of cities. Building materials such as wood, metal and bricks are being reused. However, reconditioning is often necessary, which entails significant staff costs (time), which is often and for the time being higher than the cost of the same new equipment (**visit to Cycle up in Noisy le Sec, which has launched the reuse of sanitaryware)**. This problem of extra costs and handling is addressed in the Ademe DEMOCLES project (Democles-Démolition durable, 2024).

Wood in construction waste still seems destined for energy recovery by being burnt in power plants, as mentioned on the French Ministry of Ecology website updated in 2022 (Politiques publiques-Déchets de BTP, 2018). However, it is possible to reuse wooden beams from demolished structures in new construction projects, according to (Smith et al. (2019). However, testing is also often necessary to ensure the quality of the reused product and enable subsequent insurability of the product (insurability and warranties remain a brake on reuse).

2.2 Construction waste classification

There are several ways of classifying waste, notably according to its properties or nature. Classification according to properties divides waste into 3 categories (Différentes catégories de déchets, 2017)

- Inert waste: is waste that does not undergo any physical, chemical or biological modification, does not decompose, does not burn, does not produce any physical or chemical reaction, is not biodegradable and does not deteriorate the materials with which it comes into contact in a way likely to cause harm to the environment or human health. Most of this waste comes from the building and public works sector (concrete waste, bricks, tiles, etc.),

- Non-hazardous waste: has none of the 15 hazard properties defined at European level (Different categories of waste, 2017). The rules for managing this type of waste are more flexible than for hazardous waste. Examples include bio-waste, glass and plastic waste, and wood,

- Hazardous waste: has one or more of the 15 hazardous properties defined at European level: flammable, toxic, dangerous for the environment. Hazardous waste (e.g. paint, hydrocarbons, solvents, waste contaminated with asbestos fibers, etc.) is subject to special management rules because of the particular environmental and health risks associated with its handling.

The**Figure3** represents the breakdown of waste generated in France according to a survey conducted by SDES and published in 2018 by heavy construction in the building industry, secondary construction, public works and depollution. Public works stand out for the significant amount of waste they generate, with production of 185 million tonnes, most of which is inert waste that comes mainly from earthworks and infrastructure construction, which generate concrete, stone and soil (ISDI, 2010).

However, the construction and public works sector also produces a significant amount of hazardous waste (1.85 million tonnes), with potentially harmful consequences for the environment. The structural building sector is mainly responsible for the production of inert waste (81%), but it also produces a significant share of non-hazardous inert waste (16%) such as wood, cardboard, etc. In addition, finishing and interior/exterior finishing work account for a significant 41% of non-hazardous non-inert waste. This can be explained by the use of different materials such as wood, plaster and composites, which require more complex management during sorting. Although it generates the smallest quantity of waste (4.8 million t), the depollution sector presents a notable particularity, with a high proportion of hazardous waste (21%) compared to the other waste categories. This is consistent with the nature of pollution control, which aims to neutralize or eliminate contaminants.

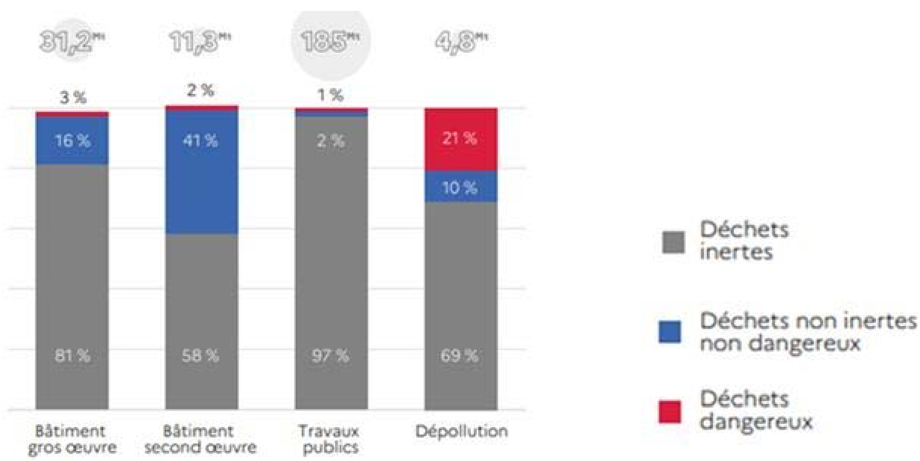


Figure3 Classification of construction waste by origin (SDES, Waste and spoil generated by construction activity in 2014).

2.3 Types of waste generated by construction and civil engineering projects

At present, the categories of waste that can be recycled are non-hazardous non-inert waste and inert waste, as these do not present any significant risks to the environment or health. Indeed, hazardous waste is subject to specific regulations and treatment and requires dedicated facilities for its management (storage, treatment) to ensure protection of water and soil, management of accidental risks, treatment and monitoring of discharges into water (Hazardous Waste, 2017).

Figure4 shows the breakdown of waste from public works sites (broad categories), whereas the type of waste from building sites is more complex. At present, the following seven waste categories have to be sorted separately on a construction site: - Mineral fractions (rubble, concrete, brick, tile, slate, ceramics, etc.) - Plastics - Metal - Glass - Paper/cardboard - Wood - Gypsum. This **sorting is called "seven-stream sorting"** (Art. 543-278 of the French Environment Code), with two types of exemption: partial or total. **Partial exemption:** it is possible to mix 6 of the 7 streams if : Waste recovery is the same as for separate collection. PLASTER must always be sorted separately, as it prevents any possible recovery of the other materials. Hazardous waste and asbestos waste must be sorted separately. **Total exemption:** for companies using the public waste management service and producing <1100 liters of waste per week - if there is less than 40m² of storage space available and - if the total volume of waste from a worksite is < 10 m3. The service providers in charge of waste collection must provide the works company with an annual certificate of waste collection and recovery **(Art.D.543-284 of the French Environment Code)**. Failure to sort waste may result in an administrative fine (source https://www.ecolusis.com/dechets-secteur-construction).

Figure4 shows the distribution of different types of waste from construction sites, including demolition. The proportion of each type of waste depends on the nature of the materials used and the construction or deconstruction processes.

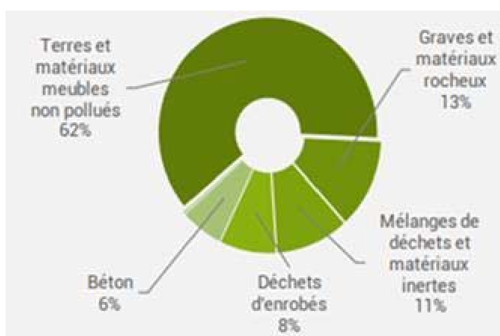


Figure4 Breakdown of materials making up inert waste from public works sites including demolition (source Réseau des CERC, diagnostics départementaux Déchets et Recyclage du bâtiment et des travaux publics entre 2010 et 2015 - CERC, 2018)

Uncontaminated soil and loose materials account for the majority of waste generated, with a rate of 62%, given the excavation and movement of large quantities of soil for projects such as tunnels and roads. Gravel and rocky materials account for 13% of waste generated by the public works sector, asphalt waste for 8% and mixed waste and inert materials for 11%. This category groups together various types of inert materials resulting from demolition or construction: earth, concrete, bricks.... This last category is generally little or not valorized. In addition, concrete accounts for 8% of the waste generated by public works (from bridges, tunnels, support structures, etc.). Although its percentage is relatively low compared to other materials, when properly sorted, concrete is fully recovered mainly as gravel for roadways (and very little used as aggregate in concretes), even though experiments (PN recybéton) and regulations (standard NF EN 206/CN (2014) Béton - Spécification, performance, production et conformité) authorize its use as a partial replacement for natural concrete aggregates

2.4 European/French regulatory framework for construction waste management

The management of construction and public works waste is governed by a set of regulations designed to ensure efficient, environmentally-friendly management. This section presents the directives, laws and regulations that set out the various practices and responsibilities involved in waste management.

2.4.1 European Construction Waste Management Protocol

The European Union's regulatory system for waste management is based on directives that have been progressively put in place to organize and improve practices in this field. This framework was established in 1975 with the European Directive on the recycling and recovery of materials, and has been developed to date with **the Directive on waste management** (Directive no. 2008/98/EC). Indeed, in order to simplify the management of construction and demolition (C&D) waste, the European Commission has drawn up a protocol as part of the Construction 2020 strategy, aimed at proposing legislation to improve Europe's transition to a circular economy and support sustainable economic growth. This protocol is intended to be implemented in all 28 EU countries, and includes best practices collected from across the Union as a source of inspiration for policy-makers and industry professionals. The measures recommended in this plan aim to achieve the target set by the framework directive stipulating that by 2020, 70% of construction and demolition waste must be recycled (European Protocol, 2016).
This guide is aimed at experts in the construction and waste recycling industry, as well as public authorities and certification bodies involved in this specific sector of activity. It highlights the importance of ensuring full transparency in waste management throughout the life cycle, in order to build confidence in recycled materials through clear traceability. It also promotes certification and regular checks based on pre-established standards and guidelines throughout the process.

2.4.2 French regulatory framework

In France, the regulatory framework for waste management has been developed in response to European directives and to address specific national issues. This framework is based on laws and decrees aimed at reducing waste production, maximizing recycling and recovery, and minimizing negative impacts on human health and the environment.

The timeline in Figure 5 illustrates the key stages in this regulatory evolution, and highlights the main laws that have shaped the current framework. French waste management regulations have evolved progressively and systematically in response to growing environmental challenges and European directives.

It all began in 1975 with the **law on materials recovery and waste disposal** (Law no. 75-633 of July 15, 1975). This law laid the foundations for waste management in France, establishing the first rules for the treatment and recovery of materials.

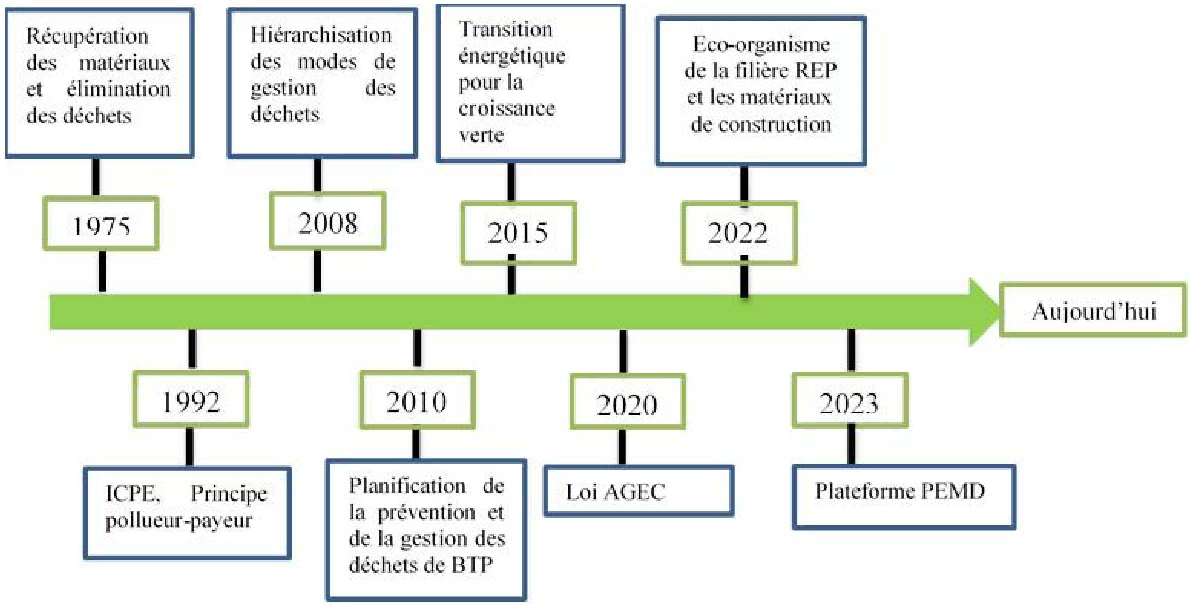


Figure5 Chronogram of French regulations on the management of construction waste (taken from the summary of regulatory documents).

In 1992, France introduced the **Polluter Pays Principle** and the concept of ultimate waste with the law (Law n°92-646) on waste disposal and Installations Classées pour la Protection de l'Environnement (ICPE). This law made waste producers responsible for the costs of managing the waste they generate. Sorting was also encouraged, reinforcing the initial regulatory framework. French regulation continued in 2008 with the **European Union's 2008 Waste Framework Directive**, which sets out the principles for waste management within member states. The transposition of this directive into French law was a key moment, imposing obligations including the waste hierarchy as a priority in waste prevention and management legislation and policy, and waste management plans.

In 2010, the **Grenelle** Act of July 12**,** 2010 (Act no. 2010-788) made it compulsory to **plan the prevention and management of waste from construction sites**. This law introduced specific strategies to reduce waste at source and promote recycling, thus integrating a global and proactive vision of waste management.

The French Law on **Ecological Transition for Green Growth** (LTECV, no. 2015-992) further strengthened these efforts by amending Article L541-1 of the Environment Code. It set explicit targets for national waste prevention and management policy, including the recovery of 70% of waste from the building and public works sector by 2020. Key measures include mandatory sorting of construction site waste, waste acceptance certificates and strict standards for construction site waste storage facilities.

In 2020, the **Anti-Waste** for a Circular Economy **Act** (AGEC, no. 2020-105) introduced new obligations for project owners, such as sorting construction site waste and targets for recovering construction waste. This law aims to transform waste into a resource and reform the circular economy in the construction sector. In 2022, a decree approved the **establishment of eco-organizations** for the **Extended Producer Responsibility** (EPR) sector for construction materials, products and equipment. EPRs are special systems for organizing waste prevention and management, under which producers, i.e. those responsible for placing construction products on the market, can be made responsible for financing or organizing the prevention and management of end-of-life waste from these products. Producers generally choose to organize themselves collectively to meet these obligations within the framework of non-profit eco-organizations, approved by the public authorities (EPR, 2017).

A new decree was then introduced in March 2023 to introduce **the PEMD diagnosis.** It applies to demolition or significant renovation operations involving categories of buildings with a cumulative surface area of 1,000 m^2 or which have hosted an agricultural activity or storage of hazardous substances (Loi PEMD). To make the diagnosis operational, CSTB has developed an online platform called the "PEMD platform", with financial support from ADEME. Its primary aim is to enable building owners to meet their regulatory obligations under the PEMD scheme, i.e. to transmit diagnostic data. To this end, building professionals (AMO, MOE, Bureaux d'Etudes...) create profiles and fill in the information on the platform, i.e. the nature and quantity of the PEMD, indications on the possibilities of reuse, recovery, recycling, the name of the project owner, and the commune in which the worksite is located (webinar followed on May 23, 2024 PEMD/CSTB). This platform enables project owners to search for PEMD deposits on the map, and to express their interest and propose recovery solutions for the deposits published on the platform. It also enables project owners to publish material deposits available for recycling or reuse. (Webinar on PEMD/CSTB, May 23, 2024) (Plateforme PEMD, 2024).

2.5 Construction waste management players

Effective implementation of the complex regulatory framework surrounding waste management relies on the collaboration of various public and private sector players. To illustrate this interaction, the flowcharts in **Figure 6** and **Figure 7** have been drawn up to present the different entities involved and their roles in the management of construction waste in France. This management involves various interconnected players and systems

In the public sector, CSTB, ADEME and CEREMA provide technical, financial and regulatory support to construction and recycling companies, including recycling and processing platforms.

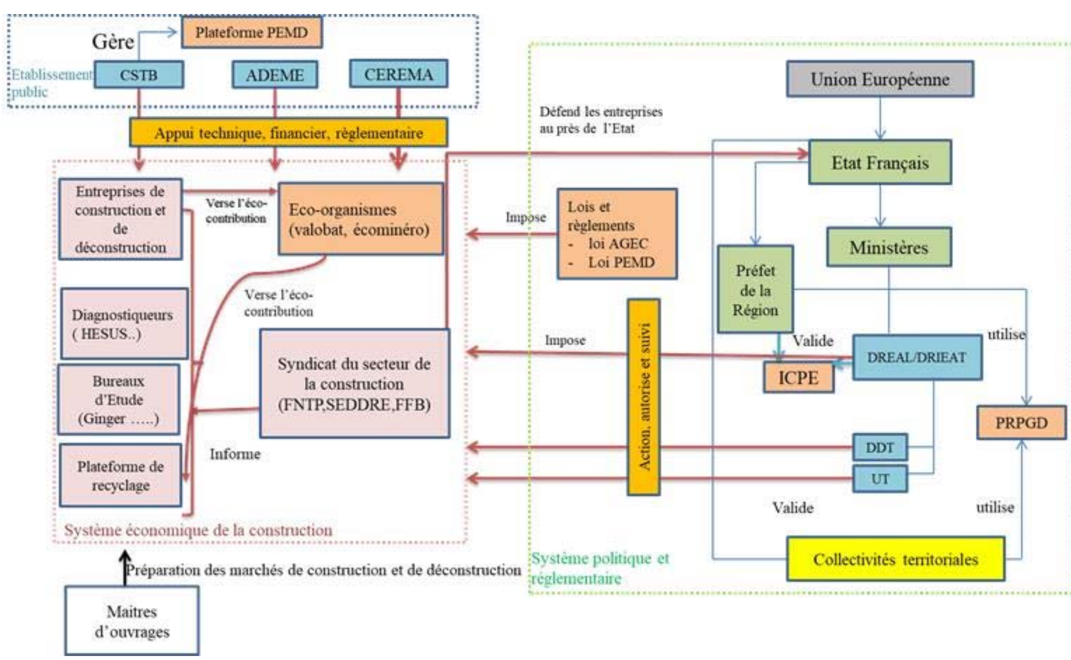


Figure6 . Diagram of the implementation of regulations relating to construction waste management

At the heart of this system, **construction and recycling companies** (**Figure 7**) are responsible for recycling and processing the waste generated by their activities. These companies collaborate **with eco-organizations** (e.g. valobat or écominéro), which are government-approved entities whose mission is to collect eco-contributions from producers, i.e. companies that place waste-generating products on the market. These funds are then redistributed to waste managers or local authorities to ensure waste collection and treatment, subject to their request (and to certain conditions concerning the management method).

In this same system, we have the **diagnosticians** who carry out a pre-demolition inventory (PEMD diagnosis) in order to propose suitable solutions and evaluate the flow of materials and types generated. These diagnosticians (Cycle up, HESUS, circlechain...) can then monitor the worksite in terms of actual waste generation, and at the end of the worksite carry out a reconciliation with what was initially planned in terms of waste generated. These companies can propose or develop diagnostic/monitoring tools to interconnect with the PEMD database. These diagnosticians, such as HESUS, take charge of waste from the construction site right through to recovery or final disposal. They provide a range of services, including waste diagnosis, logistics, evacuation and administrative procedures such as the DAP (Demande d'Acceptation Préalable des déchets), as well as traceability using developed or commercial tools to feed the PEMD database, RNDTS for excavated soil and Trackdéchets for hazardous waste.

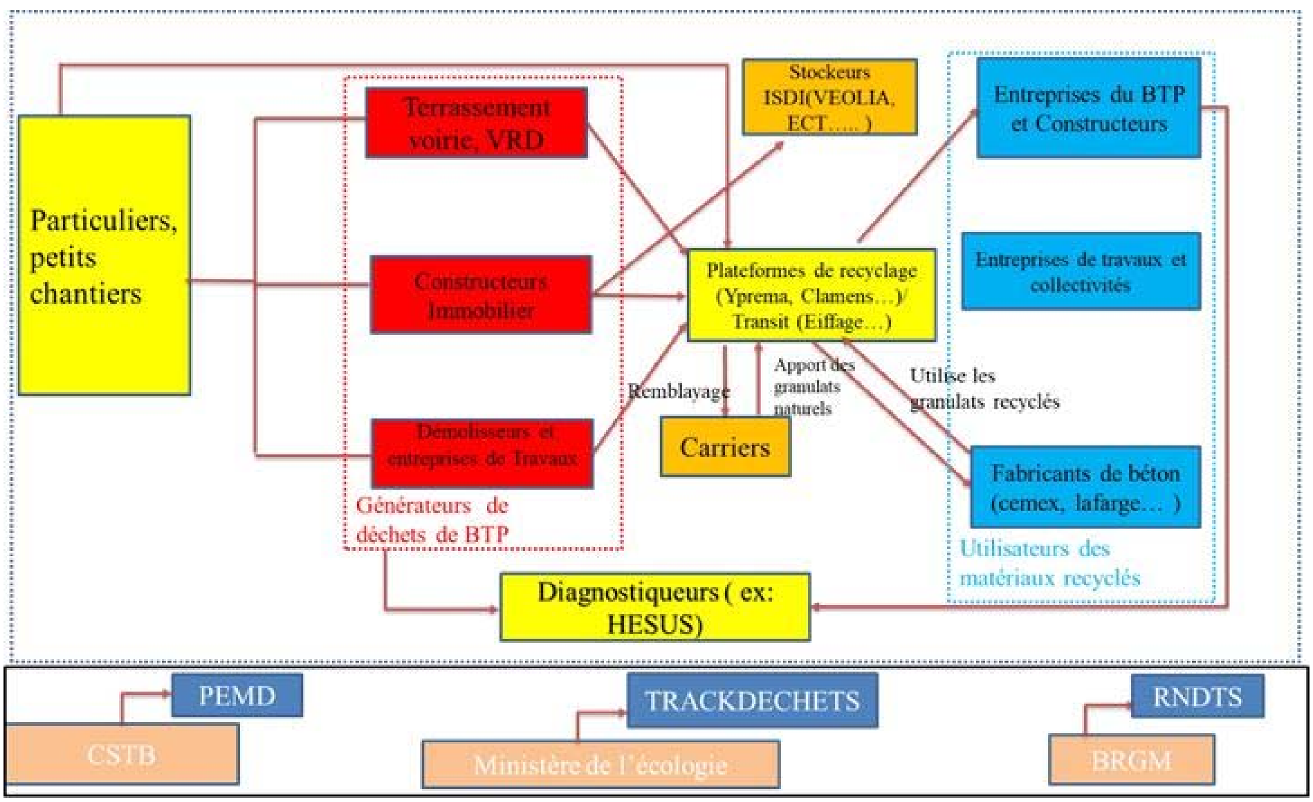


Figure7 Ecosystem of companies involved in construction waste management

Next come the demolition and earthmoving companies (who generate the waste), equipment rental services, transport and storage skips. The waste is sent either to recycling platforms or to an ISDI (in the case of unpolluted soil). Equipment suppliers such as VOLVO supply equipment such as loaders, crushers and rock breakers to recycling platforms, as well as to the demolition, earthmoving and quarrying companies that operate around them.

After processing (sorting, crushing, etc.) the waste on the platforms, the materials produced are sold to construction companies and local authorities. Recycled aggregates can also be used by concrete manufacturers such as CEMEX to make concrete, while the soil is generally sent to quarries for backfilling, which is still considered a recovery method. Platforms can also receive natural materials and mix them with recycled materials to diversify their offer. In this case, we have a double-flow transport system that optimizes the transport costs on which the financial equilibrium of operations depends, with a flow of soil to the quarries and a return flow of natural material to the platform.

The FNTP, SEDDRE and FFB building and civil engineering trade unions play a number of roles in the economic and political system, as they are responsible for informing companies about new regulations and defending their interests in dealings with the government.

In political and regulatory terms, the implementation and monitoring of the AGEC and PEMD laws are carried out by the ministries, as well as by decentralized government departments under the authority of the Ministry of Ecological Transition, such as the DREAL/DRIEAT, the DDT and the UT, under the supervision of the Prefect of the Region, notably for the validation of applications to open ICPEs in a given territory. Local authorities also play a crucial role in ensuring that directives are implemented locally. In addition, local authorities, including communes, départements and regions, are responsible for drawing up and implementing regional plans, notably the PRPGD (Plan Régional de Prévention et de Gestion des déchets - Regional Waste Prevention and Management Plan), which defines the objectives and means for preventing, reducing and recovering waste at regional level.

2.6 Construction waste recycling platforms

Several digital tools have been set up to facilitate the recycling and recovery of construction waste in France. Some unions have taken the initiative of listing the various platforms (sorting, collection, recycling, collection points, etc.) to facilitate this management, directing it to the right outlets and thus minimizing waste transport costs (and transport-related pollution/nuisance).

The **Matterio platform** (Figure8), managed by the FNTP, is aimed at project managers, local authorities and companies.

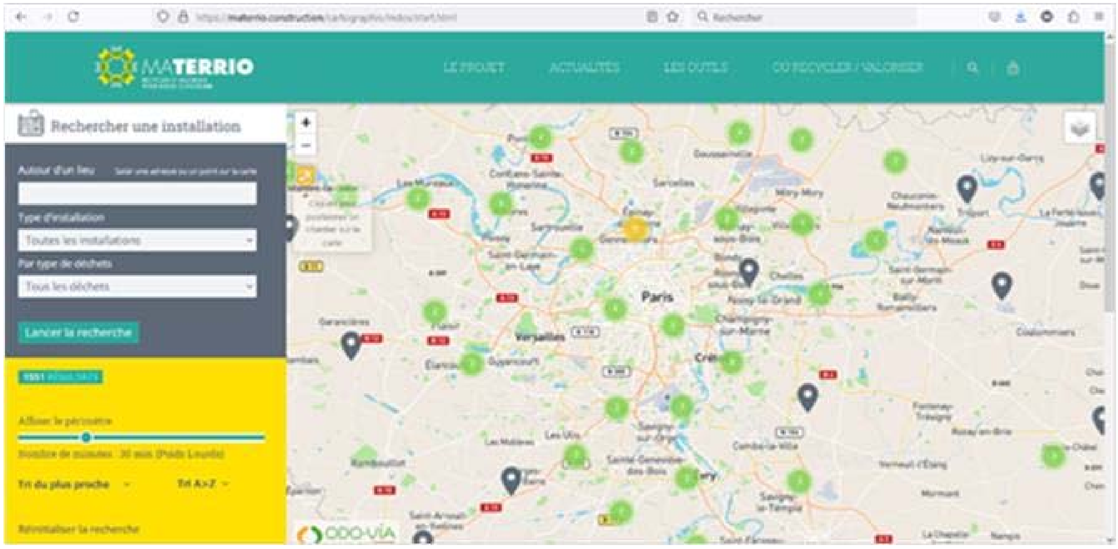


Figure8 Mapping of construction waste recycling platforms (Matterio, 2024)

This platform lists the recycling and consolidation platforms for construction waste, ISDIs and quarry backfill in France. According to this platform, there are 801 construction waste recycling platforms spread across the different regions of France.

There's also **the GEREMI tool** "Outil de gestion locale des ressources en granulat du BTP" developed by CEREMA based on the French quarry network (Geremi, CEREMA, 2024) (Figure9

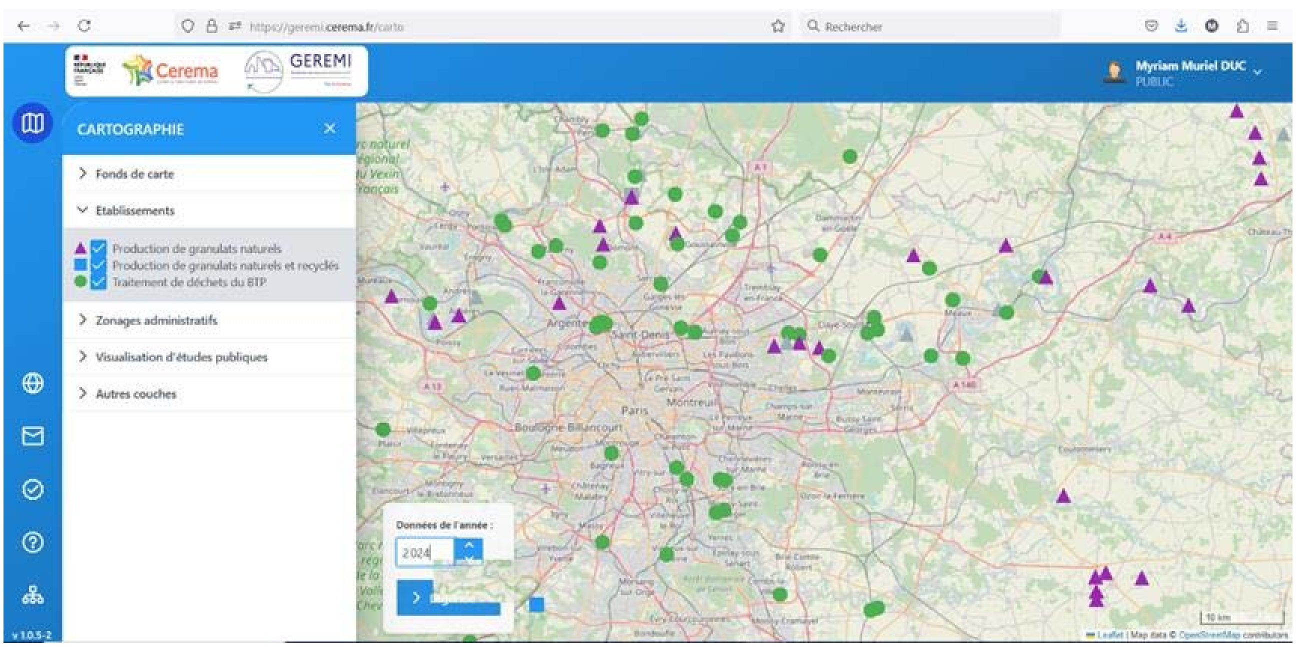


Figure9 Production map for natural and recycled aggregates (Geremi, 2024)

The cartography proposed by Geremi and implemented by CEREMA in 2024 is designed to help local authorities and the State in the planning and management of mineral resources. The tool provides information on mineral material producers and the type of materials available, whether natural or recycled. In the long term, it should help to identify the best choices of deposit or supply, in order to reduce the ecological footprint of the worksite via transport.

The FFB also offers a **"dechet-chantier.ffbatiment" tool** to help identify a drop-off point (Cartographie FFB, 2024) (Figure10). This site lists collection points throughout France, with the aim of facilitating the recovery and recycling of construction waste. The method used to list facilities and their activities is based on a questionnaire sent to processing facilities, and on the input of information provided by ADEME, notably for public drop-off centers. The centers and collectors identified as "recovery channels" provided proof that the waste was destined for recycling or any other type of recovery (FFB, 2024).

These 3 mapping tools overlap and complement each other. Improvements are planned and pooling these tools would centralize information, avoid redundancies and offer a more complete and accurate overview to all users, whatever the construction waste considered (earth, concrete gravel, bitumen, all-comers, non-hazardous non-inert waste, hazardous waste, building waste, etc.).

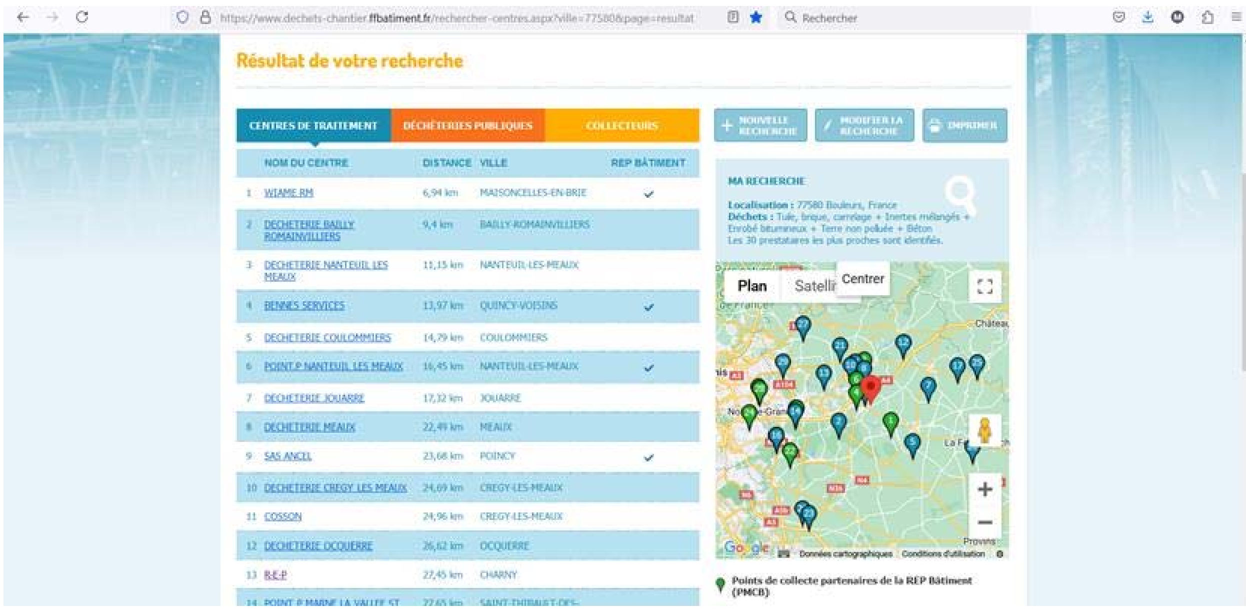


Figure10 Map of construction waste collection points (FFB, 2024)

Recycling platforms are listed on these mapping tools. These may be fixed or mobile facilities belonging to construction companies or waste management professionals. They provide a range of services (with a complete processing chain or just certain stages), such as site waste collection, waste sorting, the production of recycled materials via a treatment/process, and the sale and transport of materials to construction sites.

Most of these platforms **are ICPEs** (but not all of them are ICPEs, depending on their surface area). ICPEs are installations classified for environmental protection, and are defined in a nomenclature of sites hosting substances, mixtures or activities that present hazards or inconveniences for protected interests, namely neighborhood amenity, public health, safety and hygiene, and protection of nature, the environment and landscapes (Article L. 511-1 of the French Environment Code). French legislation has introduced laws designed to ensure the efficient management of ICPEs.

As a result, most inert waste recycling platforms are subject to different regulations depending on their **activity (transit, sorting, recycling or storage**), and must be managed in accordance with the prefectoral decree authorizing the creation and recycling activity of a platform. This decree can be of 3 types (1) recycling activity, (2) sorting and recovery, (3) storage facility. Among these orders, we have **the order of December 12, 2014** setting the conditions for waste admission to ICPEs falling under headings 2515 (crushing, grinding, screening of inert waste), 2516 (transit station for pulverulent inert waste), 2517 (transit station for other inert waste) and 2760-3 (inert waste storage facilities).

2.6.1 Waste traceability

Traceability consists in tracking waste generated by site producers through to its final recovery or disposal. Traceability has been imposed on waste producers and platforms by decree no. 2021-321 of March 25, 2021 to prevent illegal dumping and ensure a maximum recovery rate for identified waste.

In addition, producers, platforms (treatment facilities for their incoming and outgoing flows), collectors, transporters, traders and brokers are obliged to declare their incoming and outgoing flows, as are storage and incineration facilities for the treatment of non-hazardous non-inert waste, and facilities carrying out a removal of waste status as mentioned in art. R. 541-8.

The declaration of information must be made on several electronic registers (single database):

- PEMD platform managed by CSTB (for deconstruction of buildings and building sites)
- RNTDS platform (managed by BRGM) for excavated soil and sediment waste (RNDTS, 2022). The register makes it possible to precisely identify the destination or place of recovery of excavated earth and sediments. Producers transmit the register data electronically to the minister in charge of the environment (Traçabilité des déchets, 2022).
- Trackdechet platform for hazardous waste (Trackdéchets, 2024)

2.6.2 Exit from waste status

According to the French Environment Code, waste is a product or substance which the holder discards or intends or is obliged to discard. From this point onwards, these products take on a legal status governed by regulations designed to avoid any risk to the environment or public health that might be caused by their abandonment. Waste ceases to be waste once it has been treated, undergone a recovery operation, notably recycling, or prepared for reuse, if it meets the following conditions (Waste Status, 2021):

Usage	Le déchet après avoir subi une opération de valorisation, doit être utilisé à des fins spécifiques.
Marché	Il existe une demande pour ce matériau ainsi créé.
Technique	La substance remplit les exigences techniques aux fins spécifiques et respecte la législation et les normes applicables
Santé et environnement	Son impact n'aura pas d'effets globaux nocifs pour l'environnement et la santé humaine.

According to Decree no. 2021-380 of April 1(st), 2020 on waste status, any waste producer or holder can ask the competent authority to set criteria for the waste it produces or holds to cease to have waste status. The competent authority (Platform Manager, Waste Managers....) will specify the authorized waste inputs, the authorized treatment techniques and processes, and the quality criteria applicable to the materials resulting from the recovery operation.

2.7 Recycling equipment

Several types of equipment are generally used on platforms to recycle waste from construction sites. These include crushers, screeners, loaders, hydraulic rock breakers, overbands, scalpers and sorting belts. Figure11 shows the different types of equipment found on the platforms.

The **clamp loader** (Figure11 a) is used to maneuver and transport unloaded and bulky materials onto recycling platforms. It is designed to carry a large load capacity and can be fitted with various attachments for different types of work. Leading manufacturers include Volvo, Caterpillar and Komatsu, who are continually innovating to include energy-saving electric motors, advanced safety systems such as active signaling, and increased modularity. Loaders vary in size, load capacity and attachment type. Electric models are gaining in popularity thanks to their low environmental impact.

The **hydraulic rock breaker** (Figure11 b) plays a crucial role in breaking large concrete blocks into smaller, more manageable fragments for routine demolition operations. Atlas Copco and Sandvik are among the leading manufacturers to have recently introduced vibration-reducing innovations to improve operator comfort and extend the service life of rock chipping tools, which vary in power as well as noise and vibration attenuation features

The overband (Figure11 c) is used to sort ferromagnetic materials from other materials using a magnet, and is being advanced by companies such as Eriez and Goudsmit Magnetics who are developing more powerful magnets and improved automatic cleaning mechanisms. Magnetic mats vary in size and magnetic force.

The **crusher** (Figure11 d) transforms demolition materials into reusable aggregates, and can be fixed or mobile, with different types such as cone or impact jaw crushers. They are created by a number of companies such as Metso Terex Sandvik, who are developing mobile crushers that are easy to move around on worksites, and equipped with electric motors to limit greenhouse gas emissions (although this requires a power supply that limits their portability). The crushers are available in a range of sizes and mobility, and offer different crushing modes to meet specific worksite needs.

The **sifter** (Figure11 e) sorts materials by size for a particular use or for recycling. Screens can be fixed or mobile, and are used for various types of material. Powerscreen and Kleemann emphasize the modularity of equipment and the ease with which screening configurations can be modified. Screeners vary in capacity, mobility and modularity, allowing adjustments to suit specific needs

The **sorting belt** (Figure11 f) enables various recyclable materials to be sorted manually or automatically for precise separation to improve the quality of the end product; manufacturers such as BRT HARTNER and Stadler integrate robotized sorting systems and optical sorting technologies for increased efficiency to this end. Sorting belts can be adjusted to suit different material categories and levels of automation, while offering functionality for optical detection.

Technological advances on platforms now incorporate cameras and sensors to enhance user safety, while manufacturers also offer remote diagnostic systems to anticipate breakdowns and carry out preventive maintenance (one day a week is generally set aside for this, resulting in equipment downtime). The growing use of electric motors is also helping to reduce emissions and improve energy efficiency. Advances in compact, mobile machines offer adaptability to a variety of worksites, and the versatility of today's equipment means it can handle a variety of recyclable materials.

Figure11 Photos of equipment used in recycling platforms, A: Gripper loader, B: Rock breaker, C: Magnetic conveyor, D: Crusher, E: Screening machine with granulometric material separation belt, F: Sorting belt.

2.8 The recycling process

A recycling process is the set of operations involved in sorting, collecting, treating and transforming materials recovered from waste to produce recycled materials. In order to get a complete picture of this recycling process for construction waste, a diagram was proposed by Olivera et al. (2017). (Figure 12)

This diagram details the optimized recycling process for construction waste. This process, although not applied in such a comprehensive way on all platforms, comprises several key stages and uses a variety of common and specific equipment that is either mobile or hard-built on site (Figure13

This process remains "**classic"**, but it is never as complete on all platforms. It can be adapted to handle different types of waste from construction or deconstruction sites.

The process begins with a visual inspection of the incoming materials, followed by unloading and storage. Next, the materials are prepared for de-ironing, where large blocks are broken up using machines. After this stage, the materials are mechanically reduced in size using a screening machine, then passed through a crusher for further reduction. The materials are then sent to external laboratories for analysis. Finally, the recycled materials are stored in a dedicated area.

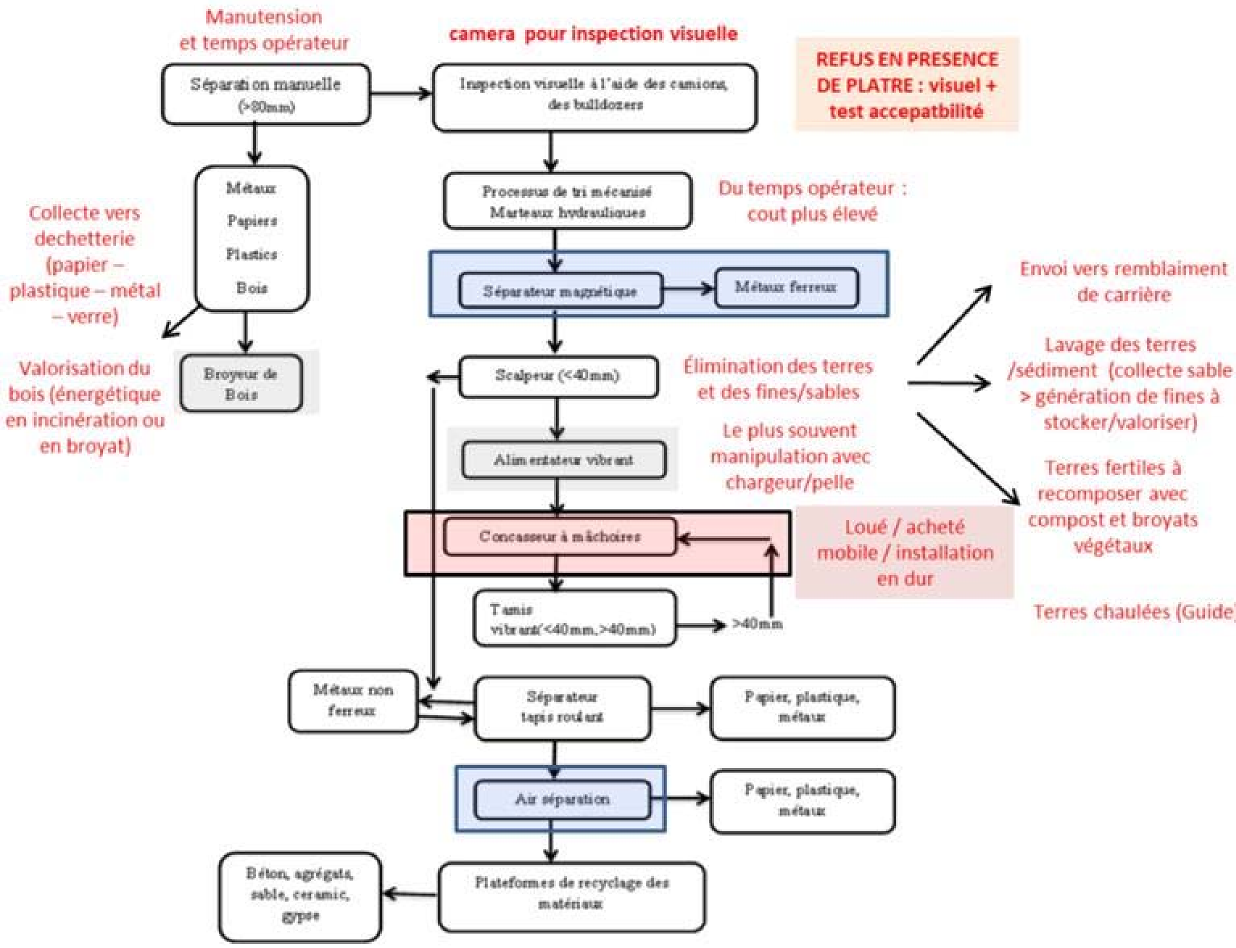
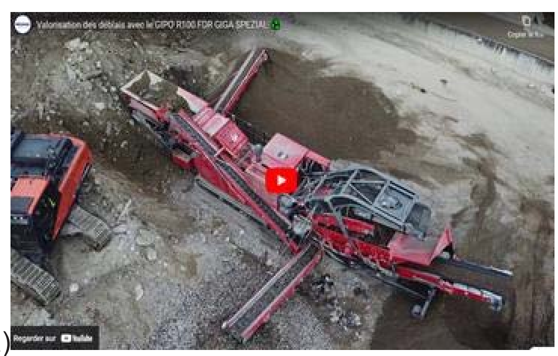


Figure12 Typical construction waste recycling process for optimal disposal. (Olivera et al., 2017) with comments/additions in color

(a)  (b) 

(c) 

Figure13 (a) All-in-one impact crusher/screener capable of going on site - 2000 t of 20/60 and 0/31.5 aggregates produced per day on site (Groupe Garonne https://www.groupegaronne.fr/le-recyclage-des-deblais-de-chantier/), (b) mobile but permanent installation on the Wiame platform with crusher (in yellow) fed by mechanical shovel, then screener/sizer (in blue) with ferrous metal separation and air separator. (c) permanent installation of a recycling platform (Yprema - https://www.yprema.fr/), permanent platform with advanced washing treatment and materials collection (CDE - https://www.cdegroup.com/fr/applications/recyclage-des-dechets).

In more detail, **the first stage of the process begins with the reception of materials.** Construction and demolition materials are transported to the recycling platform, where they undergo a preliminary visual sorting as the trucks are unloaded. This is a crucial stage, as it identifies the presence of gypsum (white). Its presence, even in small quantities, results in the entire truck being refused loading and having to take back its cargo. Visual observation by an operator during unloading can also be carried out via cameras at the truck entrance (but only the surface of the waste is examined). Visual observation can also be used to detect the presence of massive elements larger than several decimeters, which will have an impact on preparation work and the cost to the waste holder. Work requiring labor time by an operator on the platform will have to be carried out so that the massive elements can pass to the scalper/concasser.

Hydraulic hammers are used to reduce the size of the largest pieces of material in order to improve equipment efficiency (Figure11 b). The presence of wood, plastic or metals is also detected. Some platforms carry out sorting manually at this stage.

Once this initial sorting/size reduction stage has been completed, a second sorting phase is carried out, transferring the material via conveyor belts or loaders (with operator).

The conveyor transports deconstruction and construction materials to **the "scalper**" (fixed-grid separator). The main function of the scalper is to remove particles smaller than 4 mm (often earth, which can contain problematic clays in aggregates). Using this process improves the quality of recycled materials, increasing their market value and reuse potential.

This is followed by the **"Magnetic Separator**", which collects the ferrous components. The removal of ferrous metals and large debris prevents machine damage, reducing maintenance downtime and repair costs. To complete the sorting process and ensure the high quality of the gravel produced, the process can be completed **by sorting on a conveyor belt by an operator.**

Next comes the **crusher**, which can use a variety of technologies (percussion, etc.) and be electric or fuel-powered. Granulometric separation is achieved with a **trommel or vibrating sieve.** Then there's the **air separator**, which expels light elements such as plastics, fabrics or wood from the material flow.

In conclusion, installing multiple specialized machines and setting up a multi-stage process requires a substantial initial investment. Equipment purchase, installation and configuration costs can be exorbitant, especially for small businesses. What's more, complex processes require more qualified staff, increased maintenance, constant checking and high energy consumption, all of which can drive up costs in the long term. In fact, although using an optimal multi-stage process offers better quality output materials, it has an economic impact on the platform and represents an operational challenge. The implementation of such a process needs to take into account the scale of operations and the market for the materials being recycled. Nevertheless, for smaller platforms, a simplified process will generally be adopted.

3. Analysis of construction waste recycling platforms: highly variable configurations

3.1 Presentation and location of platforms visited

Several hub visits were carried out in the Ile-de-France and Rennes regions to establish the typologies of existing hubs. This section presents the location and characteristics of the main platforms visited as part of this study.

The platforms visited were YAM (Damartin-en-Goele, 77), YPREMA (Emerainville, 77), EIFFAGE (Gennevilliers 92), WIAME (Maisoncelles en Brie 77), CEMEX (Gennevilliers) and ECOSELECT (Verne-sur-Seiche 35).

Figure14 IGN map of France with location of platforms visited in the Ile de France region

Figure15 IGN map of France with locations of platforms visited in Brittany

The choice of study areas was based on the location of the two Gustave Eiffel University research centers contributing to this work, Champs-sur-Marne and Nantes, and the presence of Eiffage (for the

Eiffage platform in Gennevilliers and YAM) as a collaborator in the European CIRCBOOST project. Yprema's Emerainville platform is close to the laboratory (less than 5 km). The visit to the CEMEX platform was initiated by the Circular Economy and Urban Metabolism Chair (ECMU) of the UGE, also participating in the CIRCBOOST project, and the visit to WIAME was carried out as part of the Circular Economy days organized by the FRTP recyclers' group. The main activities of the recycling platforms visited thus vary, as does their geographical distribution. Other visits will be added at the end of 2024 and 2025 to cover all platform typologies (platforms internal to a company and not open to the outside world, as at VTMTP in Limeil Brevannes (94).

3.2 Recycling platforms visited

3.2.1 The YAM platform

Figure16 Photograph of the YAM platform, a: Material reception and control station, b: Inert soil storage area, c: Crushing with a grab loader, d: Loading materials into the mobile crusher, e and f: Recycled materials

The YAM platform, located at 4 rue Clément Ader in Dammartin-en-Goële, plays a key role in the recycling of construction and public works waste over a surface area of 2.6 ha. YAM is a platform linked to a quarry (double flow with soil input for backfilling and export of natural materials to the platform) and is owned by the Eiffage and YPREMA groups. Its function is to store and transit natural materials for most of the year. Once the stockpile has been reached, a mobile recycling unit (crushing/sorting) is brought on site with a team (on a contract basis), once or twice a year. Only a scalper and loading equipment are permanently on site. The platform processes around 100,000 tonnes of demolition waste a year, including concrete and inert soil, mainly from the deconstruction of roads and structures, with a single permanent staff member.

3.2.2 YPREMA platform Emerainville

YPREMA in Emerainville is a recycling platform for construction and demolition waste, located at 11 allée de la Briarde. Opened in 2009, the 25,000 m² facility employs 12 people. In 2023, the platform processed 86,149 t of deconstruction concrete, 30,253 t of pavement layers and 69,902 t of inert soil, from sites located on average 27 km away. It is a permanent platform with a very complete treatment process and the presence of a materials analysis laboratory (in particular sulfate detection and inert waste leaching analyses).

Figure17 Photograph of the YPREMA Emerainville platform, a: Waste reception and control, b and c: Materials storage area, d: Materials preparation, e: Ferrous metals recovery, f: Materials control and sorting, g: Crushing and screening, h and i: Recycled materials.

3.2.3 Eiffage platform

The Plateforme de Transit Eiffage, established in Gennevilliers under SAS legal status since 2018, occupies 4500 m² with a team of one to two people. It mainly collects inert materials such as soil, sludge, pebbles and rubble, from the construction industry via the road network (trucks) or barges. Around 30,000 t of waste are processed annually, with operational capacity limited by the small surface area available (not classified as an ICPE, but the same rules as for an ISDI are applied on site). It therefore serves as a transit platform.

Figure18 Photograph of the Eiffage platform, a: Waste reception and control station, b, c, d: materials storage area, e, f: recycled materials storage area

3.2.4 The CEMEX Platform

Figure19 Photograph of the CEMEX platform in Gennevilliers; a: Waste reception and control station, b, c: Materials storage area, d: Materials preparation, e: Materials crushing, f: Recycled materials storage area.

Opening in 2021, the CEMEX platform occupies 3.6 ha and employs 15 people. It is a multi-activity platform, which seems to be the form that is developing. It recycles construction waste, and stores and transports recycled materials. It takes in and recycles various types of waste from worksites located an average of 60 km away, including demolition concrete (with or without reinforcement), pavements, and ready-mix concrete rejects, given that CEMEX's core business is the supply of concrete. In 2023, the platform recycled around 42,000 m^3 of concrete. 10,000 t of demolition concrete are recycled every year, and it generates gravel (4/22 mm) and sand (0/6 mm).

3.2.5 The ECOSELECT Platform

The ECOSELET platform at Verne-sur-Seiche near Rennes (35) covers an area of 1.5 ha and employs 2 people. Opening in 2022, the platform is associated with several areas of expertise, namely public works, waste recovery and R&D. It recycles construction and public works waste, mainly deconstruction waste, rejected concrete and rubble, as well as selling and transporting recycled materials. By 2023, the platform had recycled 150,000 t of demolition and refuse concrete.

Figure20 Photograph of the ECOSELECT platform at Verne-sur-Seiche, a : materials storage, b and c: crushing, d and e: storage area for recycled materials.

3.2.1 The WIAME RM Platform

The WIAME TP platform at Maisoncelles en Brie is the one with the largest surface area, with 5 hectares in operation and 5 hectares undeveloped (with plans to install a soil washing station in 2025). This is due to its location quite far from the center of Paris. This company, which covers natural materials trading, the recycling platform and transport (4 trucks, road sweeper, 50 tippers for hire...). At the same time, Wiame TP is another (independent) subsidiary with strong links to the earthmoving, soil treatment and demolition businesses. The latter brings up the difficulty of sorting materials on site. Wiame RM was created in 2015 with 25 people. Wiame RM has opted for multiactivity, producing recycled concrete gravel as well as clay for waterproofing, fertile soil, natural materials, limed earth (0/20 mm) and riprap (blocks up to 80 cm). They are associated with a quarry in Poigny (77) that he manages for Imeris.

Figure21 Photograph of the WIAME TP platform a) site plan, b) entrance with visual control and weighbridge, c) loader, crusher and screener, d) stockpile of recycled material, e) stockpile of soil (for limed soil), f) riprap and, at the rear, a mound of fertile soil (covered with vegetation).

3.3 Analysis of platform typology and operation

For an in-depth operational analysis of recycling platforms, it is essential to consider not only the characteristics of the land and geographical location, the activities, infrastructure available nearby, the flexibility of the facilities, the consumption of resources (energy, water) and commercial management, but also the incoming and outgoing material flows and the processing capacity of each site.

To support this analysis, **Table 1** provides a summary of platform data, including type, surface area, location and area of activity.

Table1 . Characteristics of the platforms visited

names	Holder's main	Type of activities on the	Surface	Nbre	Location	Activity

	activity	platform		pers.		department
YAM (Ypréma/ Eiffage) Opening: 2022	Recycler/builders	Transit, temporary storage, preparation / recycling with mobile installation 2 times a year gravel *Waste collection center installation in progress*	2.6 ha Acquired land	1 (fixed) +3 services.	Dammartin en Goêle (77)	30km
YPREMA Opening : 2009	Specialist in platform-based recycling of construction waste	Recycling/preparation of concrete/asphalt aggregates with on-site plant+ analysis laboratory. No soil management *Waste collection center installed*	2.5 ha Acquired land	12	Emerainville (77)	35km
Eiffage Opening : 2018	Earthworks/ builder	Collection, transit Concrete gravel / earth *Loading dock for river transport*	0.5 ha	1-2	Gennevilliers (92)	30km
CEMEX Opening: 2021	Specialist in concrete manufacturing	Recycling, storage with mobile plant kept on site *Project to install a soil washing station + unloading dock*	3.6 ha Land with 5-year lease	10 (4 port/5 crushers + 1 concrete batching plant)	Gennevilliers (92)	60 km
WIAME RM Opening : 2015	WIAME = 4 companies - civil engineering, demolition, recycling platform - tipper and machine rental	Concrete-mixed gravel / soil / fertile soil / sealing clay / riprap / wood shavings / alluvial matting Project *to install a soil washing station (in progress)*	5 ha (+5 ha in reserve) Acquired land	25	Maisoncelles en Brie (77)	Mainly in Marne la Vallée
ECOSELECT/GENDROT TP Opening: 2022	Earthworks/Demolition and concrete manufacturing	Recycling, storage with mobile facilities on site. *Soil recycling platform (test phase)*	1.6 ha Acquired land	2	Verne-sur-seiche (35)	20 km

3.3.1 Land

To begin with, the surface areas of the platforms visited vary significantly: YPREMA has 2.5 ha, YAM 2.6 ha, CEMEX 3.6 ha, EIFFAGE 0.5 ha, Wiame RM 5 ha (+5ha) and ECOSELECT 1.6 ha. With the exception of CEMEX, which operates on land with a 5-year lease, all the other platforms have acquired their land, giving them operational stability. However, the possibility of planning and increasing their activities over the long term is not assured, given the pressure on land in urban areas close to sources of deconstruction materials. Land is the first limitation to setting up a platform, because in dense urban areas, land is scarce or non-existent. The search for brownfield sites can therefore be a solution, with temporary occupation of the land. Smaller transit platforms are also an option (collection of materials and processing at a rear base further away from the urban center). On-site processing, where the right-of-way is often very or too limited, remains a case of exception, albeit an optimum one. The E3S site in

Chatenay-Malabry (Eiffage), with the construction of an eco-neighborhood, remains a textbook case of this type.

3.3.2 Platform location and mapping work

Platform location also plays a crucial role in the economic equilibrium and sustainability of the platform's business, both in terms of the market and logistics (transport costs)

For example, the EIFFAGE and CEMEX platforms located in the Ile de France area (covered by the Métropole du Grand Paris or MGP) are positioned in the area with the most deconstruction/construction work (see the blue dots on the map in Figure 20). This position is favorable for obtaining a maximum number of customers, and therefore a large number of supplies. The YAM platform, which is located in a department where construction/deconstruction activity is low, serves as a rear base for receiving materials from transit platforms, but can potentially benefit from more space and a lower land cost per $m^{(2)}$.

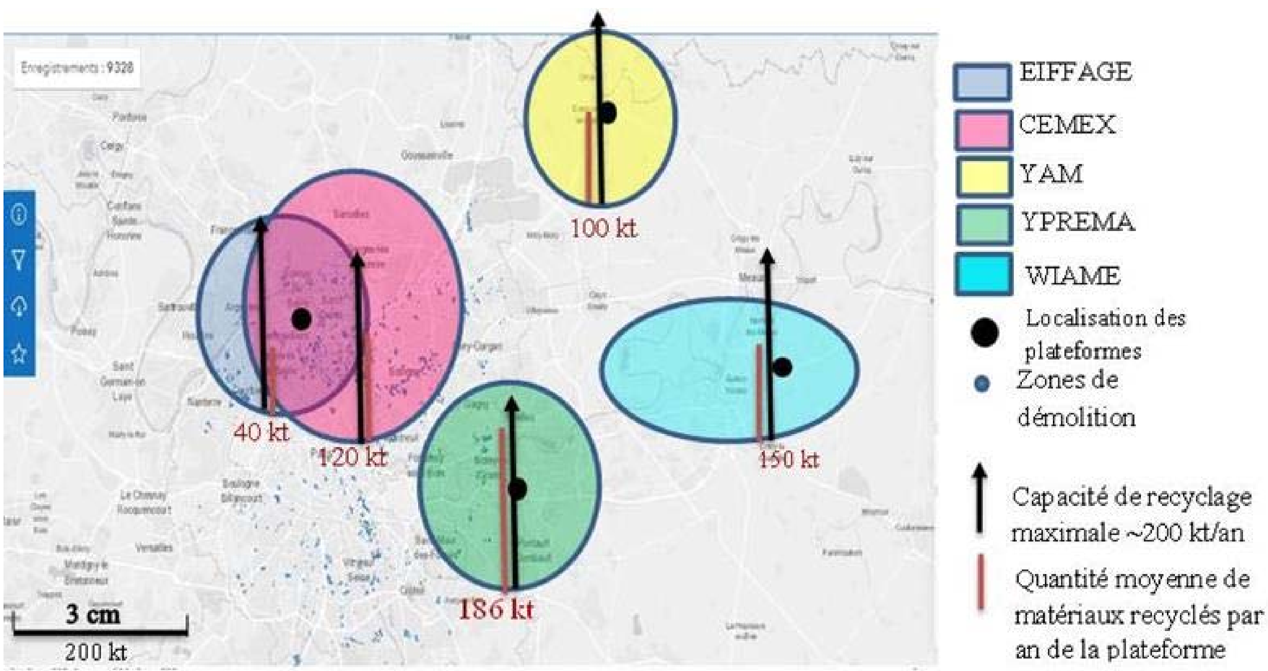


Figure22 Map showing the location of recycling platforms, their overlapping areas and the recycling capacity of each platform (Apur bati-démolition layer, 2023).

Our urban location enables us to better integrate into local supply chains and reduce transport costs for our customers.

For more detail, Figure 20 shows the location of the recycling platforms visited, with the colored discs showing the platform's action zones. The size of the arrow shows the maximum recycling capacity of each platform. The YPREMA platform appears to have a higher processing capacity than the other platforms, given the size of its hard-wall equipment. It is also the oldest platform (although it only dates back to 2009). The fact that it has been open since 2009 has favored its establishment, the development of customer relations and has enabled it to stand out in the recycling world and increase its recycling capacity over the years.

In recent years, we've seen a rapid increase in the number of platforms opening (and even closing) in response to changing needs and regulatory requirements. The emergence of eco-organizations, which remunerate platforms when waste is deposited free of charge for waste holders, has also had a major impact on the proliferation of platforms. The gaps in the network have not yet been completely identified, but a certain amount of competition is beginning to emerge between platforms (work for sales representatives who must or will have to go out and meet construction sites to find resources - a relationship of trust to be cultivated between customer and platform with the development of multiactivity).

YPREMA therefore appears to be the platform with the largest capacity, as it is also a company specializing in the recycling of construction waste, unlike other platform owners who only include recycling in their activities. For example, CEMEX, a concrete specialist, has developed a new waste recycling business in 2019, not only to recycle waste from demolitions, but also to recycle ready-mix concrete (or BPE) rejects (quantity estimated at < 1000t/month). Rejects and the ends of cast-in-block rotors are used as high-quality raw materials on the platform, in particular to be reused as recycled aggregates in the manufacture of new concrete. From a regulatory point of view, up to 20% substitution of natural aggregates is possible (Cemex traditionally produces a GBR 0-31.5 and 20-80, but also a mix category between return EPS and GBR to form a 4-22 with NF certification).

The map in Figure 20 also shows the demolition zones (blue dots) planned for the Paris region between 2021 and 2030 (Apur study, BATI DEMOLITION/Atelier Parisien d'Urbanisme (apur.org)- https://opendata.apur.org/datasets/Apur::bati-demolition/about). By superimposing the location of the recycling platforms studied in the Paris region and the platforms' zones of action, we can assess the coverage of these facilities in relation to localized recycling needs. Needs are greatest in the inner suburbs (75, 93, 94), where much construction/demolition work is concentrated, and especially along the Seine. As for the outer suburbs, demolition and construction forecasts are relatively low, as these areas have probably been developed more recently over larger areas, and urban renewal is not yet fully underway.

As for the CEMEX and EIFFAGE platforms located in Gennevilliers, they appear to be ideally positioned to serve the densely populated Ile de France region, which is very active in terms of demolition and rehabilitation close to Paris. Gennevilliers is located in areas of high construction and demolition activity close to the north-west of Paris, such as Saint Denis, Asnières-sur-Seine and Courbevoie. The proximity of the works to these platforms means they can benefit from materials for recycling and increase their supplies. For construction and demolition companies, recycling is less costly thanks to shorter transport distances. What's more, the fact that the Gennevilliers site is located close to the Seine, with loading/unloading docks, means that CEMEX and EIFFAGE can use barges to deliver materials or transport them to storage centers outside central Paris.

The YAM platform in Dammartin-en-Goële, located in the north-east of the Ile-de-France region, is further away from the main demolition and rehabilitation work zones concentrated around Paris. It can, however, serve the most scattered blue spots in the northern suburbs, such as Aulnay-sous-Bois and Mitry Mory. Its location is less strategic for supplying worksites in the inner suburbs. However, it is able to supply sites in the northern part of the greater Paris region , where recycling platforms may be limited. It also serves as a rear base for transit platforms, which are in a weak position due to their small footprint.

YPREMA's Émerainville platform is well positioned to serve the south-east of Paris and the surrounding area. This region also shows strong demolition and rehabilitation activity, particularly around Montreuil, Vincennes and Créteil, as well as the Marne la Vallée construction zone. The presence of this platform in the south-east zone enables us to effectively manage waste flows from these construction sites and to support the creation of green spaces in adjacent areas (presence of ISDI storage center and landscape recreation zone with ECT in Moisssy-Cramayel for example - https://www.groupe-ect.com/realisations/parc-moissy-cramayel/). As for the WIAME RM platform, located further east in the Paris region, it is located in areas where demolition and construction activity is relatively low, but its supply remains important given its capacity to receive materials over a wide area and its "earth" activity, which is little or undeveloped on other platforms. It works mainly with construction projects in the Marne la Vallée area, from Bry sur Marne to Bailly-Romainvilliers, an area between 20 and 25 km long.

3.3.3 Business specialization and multi-activity

The activities carried out on the platforms visited reflect a diverse range of specializations. YAM/Eiffage (recycler associated with a construction/earthworks company Eiffage with an associated quarry) focuses mainly on the storage and recycling of concrete gravel, mixed gravel (but not earth). CEMEX (concrete supplier associated with a barge transport network and quarries) is expanding its activity, and ECOSELECT (earthworks/demolisher and concrete manufacturer) is fairly versatile, with recycling, storage and on-site mobile facilities. YPREMA (recycler) specializes in concrete and aggregate recycling with their fixed installation, while Eiffage, like CEMEX, is expanding its business by getting involved in the collection, transit and storage of demolition waste and soil. Wiame RM is notable for its versatility, with activities including the recycling of concrete and mixed gravel, the production of fertile soil, waterproofing clay, riprap and even the possibility of crushing wood.

We can see that many companies are setting up platforms even though their core business is not recycling.

3.3.4 Technical equipment and recycling processes

In terms of equipment, YAM, EIFFAGE, CEMEX and ECOSELECT mainly use mobile plants, offering flexibility and rapid adaptation to changing needs, even if some of these mobile plants are used as fixed installations. Nevertheless, they offer compact, space-saving installations. YPREMA, on the other hand, uses fixed installations including an in-house laboratory, offering advantages in terms of processing and quality control, but limiting flexibility. As for equipment ownership, CEMEX and Wiame RM own their equipment, while YPREMA, ECOSELECT and YAM opt to lease all or part of their plant and equipment (impact on maintenance and equipment renewal depending on varying needs).

The recycling process adopted by YPREMA, recognized for its completeness and efficiency, is similar to the process proposed by Olivera et al (2017) (Figure 12). This process, shown in Figure 22, incorporates an in-house laboratory and several processing stages, guaranteeing rigorous quality control and autonomous management. The other platforms have a simpler process which uses equipment that is partly permanently on site or leased for crushing, screening and external laboratories for analysis and control of recycled materials.

At Yprema, after the arrival of materials and an initial visual check, they are unloaded and stored before preparation (in the presence of white gypsum - a few kg in a truck and the truck is refused). This preparation then includes scalping to eliminate fine materials (soil stored for quarry backfill) and breaking up large blocks using hydraulic machines by an operator (one by one). This time-consuming stage entails additional costs. A vibrating feeder then directs the material to a stationary crusher for mechanical size reduction. A key step in this process is the use of an electromagnet to separate scrap and a blowing separation of light elements (plastics, wood...), followed by a sorting station (measurement to ensure controlled quality). Final screening scalps products by desired particle size, and precedes in-house laboratory analysis. Using an external laboratory means additional delays and dependence on external services for quality validation. Note that rapid tests are often carried out on site (sulfate kit, PAH kit...) to perform reconnaissance on arrival of materials in case of doubt or suspicion of pollution. An in-house laboratory enables rapid analysis and immediate adjustment of recycling parameters, optimizing the efficiency and quality of the final product. This autonomy is a major asset, especially for platforms that aim to offer complete, high-quality solutions. On the other hand, by relying on external laboratories, the operator can benefit from cutting-edge technologies or methods available in specialized laboratories, even if this means less responsiveness.

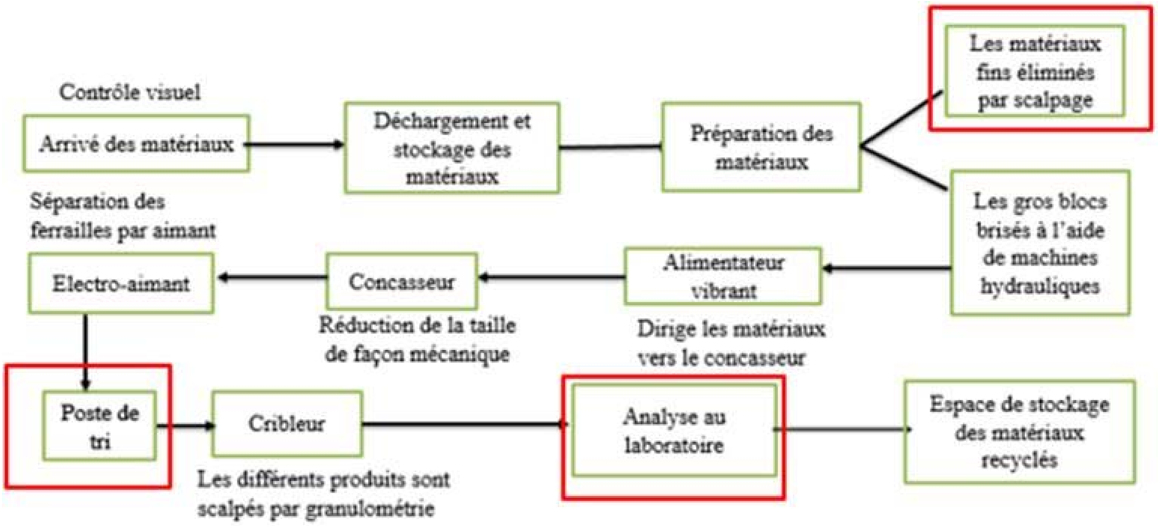


Figure23 Recycling process on the YPREMA platform

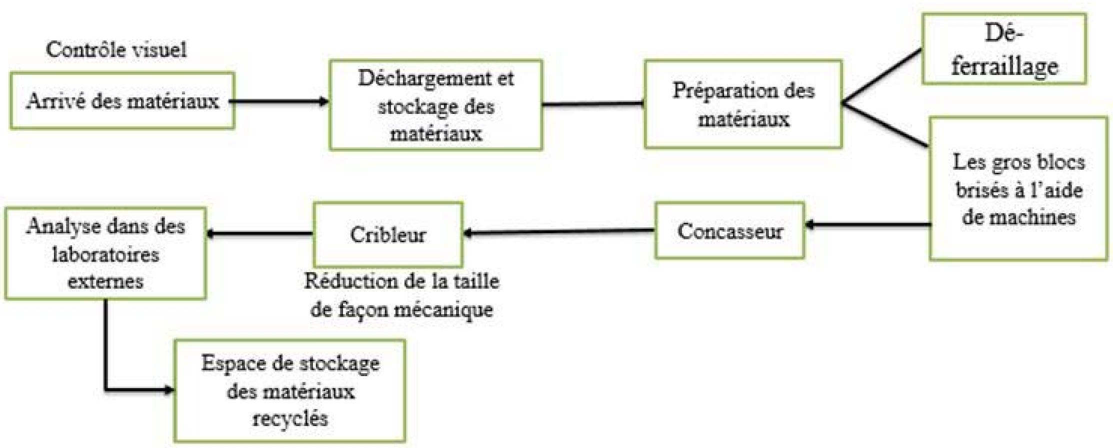


Figure24 Conventional recycling processes used on other platforms

In comparison, the second process is more simplified and straightforward. After visual inspection and unloading of the material, material preparation includes de-ironing and breaking of large blocks using machines, but no mention of scalping of fine material. Size reduction takes place after passing through a crusher. A peculiarity of this process is the reliance on external laboratories for material analysis, which can imply additional delays and dependence on external services for quality validation. However, this could benefit from state-of-the-art technologies or methods available in specialized laboratories. Integrating an in-house laboratory into the first process enables rapid analysis and immediate adjustment of recycling parameters, thus optimizing the efficiency and quality of the final product. This autonomy is a major asset, especially for platforms that aim to offer complete, high-quality solutions. On the other hand, the second process, by relying on external laboratories, could benefit from cutting-edge technologies or methods available in specialized laboratories, even if this means less responsiveness.

While recycling in a fixed, complete platform offers advantages in terms of quality and control, thanks to the integration of an in-house laboratory and numerous processing stages, this process requires a significant land area and financial cost, as well as a large flow of incoming materials, which can be a major obstacle, especially in a context of competition between platforms around concrete. Smaller platforms, or those located in expensive land areas, may find this approach less profitable due to high maintenance and operating costs relative to the revenues generated. On the other hand, a simplified process, with analyses carried out by external laboratories, offers maintenance flexibility and reduced operating costs. Such facilities make it possible to benefit from advanced technologies without the fixed costs of an in-house laboratory and fixed equipment, and are better able to adapt to variations in the quantity and type of waste available.

3.3.5 Transportation

In terms of transport, EIFFAGE and CEMEX are distinguished by their use of two types of transport (river and road), thus reducing costs and carbon footprints. This is a specific feature given their location at the Port of Gennevilliers (with other platforms nearby). The platforms' areas of activity leave it up to the customer to decide whether to hire hauliers or buy materials directly, with delivery prices included. Wiame RM is unique in that it has its own trucks, just as CEMEX has its own fleet of barges (around 100 non-motorized barges with 13 pushers). Eiffage, Yam or Yprema do not manage transport, but may in some cases have preferred associate carriers for delivery.

3.3.6 Material flows and platform capacity

Table2 shows the inflows, material types and outflows of the various platforms visited.

Table2 . Typology of incoming and outgoing platform flows.

Platform names	Incoming flows	Types of materials	Outgoing flows
YAM	100 000 t	deconstruction, inert soil	100 00 t aggregates, sand, sands
YPREMA	186 304 t	Deconstruction concrete, pavement layers and inert soil.	182,282 t of concrete, industrial products and limed earth
EIFFAGE GENNEVILLIERS	30 000 t	Waste (inert soil / sludge / stones / rubble)	30,000 tonnes
CEMEX GENNEVILLIERS	120 000 t	Deconstruction concrete, inert earth, backfill and rubble	42,000t of recycled concrete, recycled gravel, aggregates
ECOSELECT/ GENDROT TP	150 000 t	Deconstruction concrete, inert soil, backfill,	Industrial and mixed aggregates.
WIAME RM	--	Inert soil and boulders, concrete (gravel/pebble), road deconstruction (mixed gravel, milling/planing) + alluvial sand/gravel	--

Incoming flows concern materials arriving at the platform, whether from demolition or construction sites. Outgoing flows include materials that have been processed and recycled on the platform and are ready for use, such as recycled aggregates, chippings and sand. Agreements are in the process of being signed to gain access to internal platform data in order to quantify more precisely the flows of each type of material: those that are demanded/consumed, those that are available but little demanded, those that are refused or sent to quarry storage/recharge. This detailed analysis should make it possible to identify recovery routes. Nevertheless, we note that soil management is often dissociated or non-existent (almost systematically sent for backfilling), crushed concretes are all consumed (not enough stock to meet demand, essentially for road construction, and little or no use of GBR in concrete, even though it is authorized). Each company, with its own speciality, directs the platform, but we're moving towards a multi-activity approach, with the creation of a collection point for artisans (so as to have a single place to deposit materials and supply them), which will reduce empty trips. The cost of transport (and therefore the distance to be covered) is what costs (balanced business model).

Material flows vary for each platform. YPREMA has a high recycling capacity, with 186400 t of recycled aggregates per year, thanks to its relatively large surface area, fairly complete equipment compared to other platforms, and a large number of personnel (compare ratios of personnel to surface area and personnel to annual sales). Furthermore, these parameters (surface area, activity, flows) play an important role in the regulations applied at each hub. In fact, all these platforms are considered ICPEs, with the exception of the EIFFAGE platform, which has insufficient surface area and only handles transit and storage (although Eiffage applies the same rules as for an ICPE).

Lastly**, capacity for future expansion and adaptation** are key points for certain platforms. For example, YAM is in the process of installing a landfill site, CEMEX is planning a soil washing station, as is WIAME RM, and ECOSELCET is planning to develop a soil recycling activity, demonstrating the platforms' openness to markets other than aggregate recycling and their anticipation of future market needs.

3.3.7 Resource consumption

The consumption of resources such as water on platforms to limit dust during the summer or to clean machines also remains a problem on some platforms. Other platforms, such as CEMEX, use basins to collect water, which is then cleaned directly on the platform. The consumption of resources such as water on the platforms to limit dust during the summer, clean machines (washing station for vehicles leaving to drive on the roads) or even material washing station must be managed on the platform. They are all equipped with runoff collection basins on the platform (water management with collection of fines through sedimentation). This is one of the obligations of an ICPE. Borehole water abstraction is possible in the case of supplying an aggregate washing station, as envisaged by Wiame RM (recycling of process water with a treatment station). Cemex would have to use part of the water from the dock on which the barges transport the materials. Wiame RM practices eco-pasturing on its site (with permanent animals), with a switch to electric vehicles for their fleet and soon autonomous photovoltaic power supply. Yprema, for its part, has planted beehives and developed a biodiversity-friendly approach.)

3.3.8 Conclusion

Each platform has its own specific strengths and weaknesses, influenced by its land, location, type of activity and equipment. This diversity makes it possible to meet a wide range of needs in the recycling sector, while at the same time requiring continuous adaptation to regulatory changes and environmental requirements.

4. Suggestions for improvement and recommendations

Recycling platforms play a crucial role in reducing the landfilling of construction and public works waste, helping to preserve natural resources and promote the circular economy. Indeed, these platforms implement tools to guarantee the traceability of incoming materials and carry out analyses after each recycling campaign to maintain material quality. However, some platforms do not systematically analyze incoming materials, which can have a negative impact on the quality of recycled materials, especially in terms of sulfate concentration. However, the platforms we visited all paid extreme attention to the presence or absence of gypsum when unloading trucks.

At present, most platforms have limited recycling capacity, but this seems to be in line with demand and the presence of competitors, some of whom are close by. For the most part, they focus specifically on a single sector: the production of recycled concrete aggregates (GBR) and milled pavement to make mixed gravel (no brick/tile, gypsum, earth, natural pebbles, mixes or pavers/blocks, which could be collected subject to time-consuming and staff-intensive manual sorting). The main factor holding back production is an insufficient supply of demolition waste. What's more, although the recycling of construction waste is fairly profitable, it requires a skilled workforce due to the arduous nature of certain tasks. State support for this sector through schemes such as EPR (and the presence of eco-organizations) has led to a proliferation of platforms, although the system that is being set up is not yet optimal (sometimes very long deferred payments). Selective sorting on demolition sites remains an imperative, and the management of 7 flows facilitates the work of platforms and guarantees the quality of aggregates. However, new composite materials and complex multi-layer bonded materials will make selective sorting more complex, if not impossible. The development of eco-design of products is therefore necessary to prepare for the demolition stage.

To optimize the performance of recycling platforms, improvements can be proposed:

- Land optimization and identification of new installation zones (potentially in the short/medium term).
- Develop interconnected traceability tools using scales/cameras or even on-line material analysis (simplify declarations and automatically feed data into databases).
- Diversification of recycling (development of new channels (raw earth, limed earth, soil washing....) and multi-activity so that all services are available in the same place.
- Reinforce the analysis of incoming materials or carry out searches on the site of origin of materials on BASOL or BASIAS sites (automated cartographic search tool set up at Wiame RM).
- Adjustment of working hours for staff (to take account of maintenance days)
- Opt for mobile machines on smaller platforms with options to reduce noise and dust (miniaturization of equipment with a "pocket" size.
- Switch to electric power for equipment and supply via green energy

- An approach focusing on biodiversity and the insertion of the platform as a desirable object in the urban context.

5. Conclusions

In conclusion, the management of construction and public works waste represents a major challenge for all players, whether private or public, in order to meet both national and European regulatory requirements. The LTCV law requires that 70% of demolition and construction waste be recycled. However, recent SDES data show that this target has not been met. In France, the recycling rate for mineral waste is 60%, while 10% is used for backfill, and 30% ends up in landfill or as landfill (SDES, 2022). This situation highlights the need to review and improve current waste management practices for construction and demolition waste. It should also be noted that changes to the regulations governing the management of sediments from port and canal dredging will also reshuffle the deck, as large quantities of quite specific fine materials will have to be taken into account.

Recycling platforms play an essential role in waste reduction, notably by recycling concrete, rubble and pavements. However, their capacity to process all construction waste is limited. In fact, it's not just concrete and rubble that are involved; other materials are also generated, notably those from the finishing trades, which are still little recovered. A survey carried out by INDURA Auvergne Rhône-Alpes and CEREMA among 265 professionals reveals that this low level of recovery is due to a number of factors, such as the difficulties of transitional storage of deconstructed materials and the lack of guarantees for reused materials (https://www.cerema.fr/system/files/documents/2022/06/sequence38_martinez_charlotte_daniel_tartonne_indura.pdf).

Despite a number of regulations put in place by the State, such as EPR and the PEMD platform, and the tools developed by public players (matterio platform, FFB, Geremi tool) to facilitate waste management, it is clear that these challenges persist, particularly with regard to sorting at source, territorial coverage and "effective" waste recovery. In addition, the measures taken by the French government to strengthen the territorial coverage of collection and sorting facilities, and to regulate landfill sites according to the hazardous nature of the waste, are essential. Further efforts are needed to increase the density of this network and thus reduce illegal dumping, while making recycling more competitive.

6. References

Moschen-Schimek, Julia, et al. "Critical Review of the Recovery Rates of Construction and Demolition Waste in the European Union - An Analysis of Influencing Factors in Selected EU Countries". Waste Management, vol. 167, July 2023, pp. 150‑64. DOI.org (Crossref), https://doi.org/10.1016/j.wasman.2023.05.020.

Archive:Waste Statistics. https://ec.europa.eu/eurostat/statistics/explained/index.php?title=Archive:Statistiques_sur_les_d%C3%A9chets.

CERC (2017) Waste and recycling in construction and public works in France: contributions from the CERC network, http://materrio.construction/mediatheque/pages/Dechets_et_recyclage_BTP_France_(1).pdf

Different categories of waste | Ministère de la Transition écologique et de la Cohésion des territoires. https://www.ecologie.gouv.fr/politiques-publiques/differentes-categories-dechets

Hazardous waste | Ministère de la Transition écologique et de la Cohésion des territoires. https://www.ecologie.gouv.fr/politiques-publiques/dechets-dangereux.

Installation de stockage de déchets inertes (ISDI)". Les services de l'État dans le Nord, https://www.nord.gouv.fr/Actions-de-l-Etat/Environnement/Gestion-des-dechets/Installation-de-stockage-de-dechets-inertes-ISDI.

Ecorys (2016) European protocol for the treatment of construction and demolition waste, ref: Ref. Ares(2016)6914779

Law no. 75-633 of July 15, 1975 on waste disposal and materials recovery.

"LOI no 92-646 du 13 juillet 1992 relative à l'élimination des déchets ainsi que aux installations classées pour la protection de l'environnement (1)". 92-646, July 1992.

"Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance)". OJ L, vol. 312, November 19, 2008, http://data.europa.eu/eli/dir/2008/98/oj/fra.

LOI n° 2010-788 du 12 juillet 2010 portant engagement national pour l'environnement (1) ". 2010-788, July 2010.

LOI n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte (1) - Légifrance. https://www.legifrance.gouv.fr/jorf/id/JORFARTI000031044847.

LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire (1) - Légifrance. https://www.legifrance.gouv.fr/jorf/id/JORFARTI000041553782.

Cadre général des filières à responsabilité élargie des producteurs | Ministère de la Transition écologique et de la Cohésion des territoires. https://www.ecologie.gouv.fr/politiques-publiques/cadre-general-filieres-responsabilite-elargie-producteurs.

Arrêté du 26 mars 2023 relatif au diagnostic portant sur la gestion des produits, équipements, matériaux et déchets issus de la démolition ou de la rénovation significative de catégories de bâtiments et abrogeant l'arrêté du 19 décembre 2011 relatif au diagnostic portant sur la gestion des déchets issus de la démolition de catégories de bâtiments - Légifrance. https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000047506328.

A mineral resource management tool developed by Cerema | Cerema. http://www.cerema.fr/fr/actualites/outil-gestion-ressources-minerales-developpe-cerema.

Find a collection point near your worksite.: https://www.dechets-chantier.ffbatiment.fr/ .

Traceability of waste, excavated soil and sediment | Ministère de la Transition écologique et de la Cohésion des territoires. https://www.ecologie.gouv.fr/politiques-publiques/tracabilite-dechets-terres-excavees-sediments.

The RNDTS | Registre National des Déchets application. https://rndts-diffusion.developpement-durable.gouv.fr/fr/lapplication-rndts.

Trackdéchets | Tracking waste safely. https://trackdechets.beta.gouv.fr/.

Décret n° 2021-380 du 1er avril 2021 relatif à la sortie du statut de déchet - Légifrance. https://www.legifrance.gouv.fr/jorf/id/JORFARTI000043327063.

matterio. https://materrio.construction/pages/sortie-de-statut-de-dechets-le-passage-par-une-installation-n-est-plus-obligatoire.

Oliveira Neto, Raul, et al. "An economic analysis of the processing technologies in CDW recycling platforms". An economic analysis of the processing technologies in CDW recycling platforms". Waste Management, vol. 60, February 2017, pp. 277-89. ScienceDirect, https://doi.org/10.1016/j.wasman.2016.08.011.

"Waste production and recycling in 2021. Statistical data and studies for climate change , energy, environment, housing and transport, https://www.statistiques.developpement-durable.gouv.fr/production-de-dechets-et-recyclage-en-2020.

https://www.cerema.fr/system/files/documents/2022/06/sequence38_martinez_charlotte_daniel_tartonne_indura.pdf

BATI DEMOLITION | Atelier Parisien d'Urbanisme (apur.org)

7. Appendixes

Appendix 1 - Platform survey

Questionnaire for deconstruction waste recycling platforms

Dear Platform Manager,

Before you start answering this questionnaire, we would like to inform you of the importance we attach to protecting your professional data. Your answers and data will be as confidential. To this end, a specific document may be signed to render your contribution anonymous. This feedback will contribute to the work being carried out as part of the European CIRCBOOST project.

Name of interviewer :

Administrative data :

Platform name: Address:
Date of visit/exchange: Persons
contacted :
Name of persons in charge:
Legal status :
Platform area: Number
employees :
Platform opening date: Sales (2023) :

Technical data :

1. What are the different methods of collecting construction waste?
2. How many people are needed to run the platform?
3. What types of construction waste does your platform accept?
4. Do you sort construction waste on your platform? If sorting is carried out, what equipment and technologies do you use?
5. What are the different input flows (quantities)? Where do they come from?
6. What are the different output flows (quantity) (quantity)? What is the processing capacity of your platform in terms of volume of construction waste processed per day/week/month/year?
7. What are the factors limiting this capacity (land area, number of employees, equipment

capacity, etc.)?

8. What volume of waste was actually processed in 2023? How much of it was recycled?
9. What traceability tools/measures do you use on the platform? What would be your needs in terms of traceability? Which means do you think would be simpler or more elaborate?
10. What data, information or techniques do you use to assess platform's efficiency (rate of materials recycled, nature of materials sent for storage (refusals?), materials not recovered (no final take-back), quality of materials recycled)?
11. How do you measure the operational efficiency of your platform in terms of recycling rates and reduction of waste sent to landfill? What key performance indicators (KPIs) do you use to assess your platform's operational performance?

Economic data :

12. Platform energy consumption (type and quantity)
13. Land associated with the platform
14. Average value of sales prices (or price grid according to products leaving the platform)
15. is waste received on the platform?
16. Average price for waste reception (varies by type?)
17. The role of eco-organizations?
18. Do you have any competitors in your field? What difficulties do you encounter in terms of business planning?

Operational data

19. What are the types and numbers of equipment used on the platform, with hourly volume (average, min, max)? Is the equipment fixed or mobile? What is the processing capacity of your platform in terms of volume of construction waste processed per day/week/month?
20. What are the main operational difficulties your platform faces in the recycling process construction waste?
21. How do you manage non-recyclable or contaminated waste on your platform?
22. What partnerships or collaborations do you have with other industry players to optimize your recycling operations?
23. Are your supplies regular, increasing, decreasing, variable, seasonal? Do you have the capacity adapt (flexibility) and increase reception/recycling capacities?
24. What investments are planned or underway to improve your platform's operational efficiency?

Regulatory data :

25. What is the history and development of the platform? How was the choice of location made and were the authorizations complicated to obtain? ICPE procedure?
26. What environmental standards and regulations must your platform comply with in the recycling process for construction waste? Do you have a system dust abatement, noise measurement, impact on environmental biodiversity, water collection and treatment system?
27. What is the procedure for removing waste from your platform? Do you have any government-imposed threshold values that must be met after waste processing to ensure that recycled materials are reusable?

28. How is your platform adapting to technological and regulatory developments and innovations in the field of construction waste recycling?
29. Given that platforms are classified installations for the protection of the environment, what are the constraints imposed by State? Do you have any controls, of what type and by whom?
30. What partnerships or collaborations have been set with institutional players (State, Region, City, ADEME, etc.)?

More broadly

31. How does your platform contribute to reducing environmental footprint of The construction industry?
32. Do you have any initiatives in place to raise awareness and involve the construction industry in the waste recycling process?

Appendix 2 Details of the visit to the Dammartin en Goele platform

The YAM platform, located in the heart of Dammartin-en-Goële, is a crucial link in the recycling process for construction waste. Located at 4 rue Clément Ader, the 2.6-hectare facility is a central hub in the management of residues from demolition and deconstruction. Since its commissioning, the platform has been resolutely committed to contributing to the circular economy by offering an efficient and sustainable solution for the treatment of construction and public works waste. Under the management of Mr. Emmanuel SARTHER, the platform operates with a small staff of just two employees, who face the constant challenge of meeting growing demand while maintaining smooth operations. YAM's primary vocation is to receive and process various types of deconstruction waste, in particular demolition waste, reinforced and non-reinforced concrete, and inert earth. Around 100,000 tonnes of waste are processed annually, mainly from the deconstruction of roads and structures.

Figure25 Photograph of the YAM platform at Dammartin en Goêle

At the heart of its operations, YAM implements a manual sorting method carried out by staff and constant vigilance with regard to the quality of incoming materials. Waste deposited on the platform is pre-sorted by the customer and sent to the appropriate equipment for treatment. However, despite these efforts, the platform's operational capacity is sometimes limited by its small workforce and the constraints of its land surface. To ensure traceability of incoming materials, the customer submits a request for prior acceptance, and YAM uses delivery notes at the time of delivery. To guarantee the quality of materials leaving the platform, they carry out laboratory analyses and sulfate tests every day after each treatment. These analyses are also aimed at assessing the efficiency of the recycling process and maintaining high standards of environmental quality. With a view to continuous improvement, the platform is also exploring ways of strengthening its partnerships and collaborations in the industry, notably by further prospecting to attract demolition waste. In addition, investments in mobile equipment could help to optimize and meet current operational challenges. Despite the challenges it faces, YAM remains a key player in the responsible management of construction waste, helping to promote a more sustainable environment and support the transition to a more efficient and environmentally-friendly circular economy.

Appendix 3. Details of the visit to the YPREMA platform in Emerainville

YPREMA Emerainville is a construction and demolition waste recycling platform located at 11 allée de la Briarde Emerainville. Opened in 2009, it covers an area of 25,000 m² and employs 12 people. The platform plays a crucial role in construction and public works waste management, handling mainly sorted inert waste, such as concrete, pavement layers and inert soil. On average, these materials come from sites located 27 km from the platform, with each ton traveling around 35 km. In 2023, YPREMA Emerainville processed 86,149 tonnes of deconstruction concrete, 30,253 tonnes of pavement layers and 69,902 tonnes of inert soil. To ensure the traceability and quality of incoming materials, the customer is required to submit a prior acceptance request including all the characteristics of these materials (quantity, quality of materials, presence or absence of gypsum or whether they are demolition or construction waste, etc.). If the request is accepted, the customer receives delivery notes and the weighing is recorded at the time of delivery. When the trucks arrive at the platform, they are subjected to a visual inspection by camera to check that they are clean and free of wood, plaster and plastic. If they are, they are rejected and subjected to a rapid test to confirm the presence or absence of gypsum. Materials are then stored in dedicated areas and checked again on unloading. In addition, materials are prepared using a hydraulic rock breaker and de-fertilization before being subjected to treatment processes. Processing begins with a feed hopper into which an operator dumps the raw materials, which are then automatically conveyed to a series of machines designed to reduce them to reusable products. The materials are then sorted by operator from the monitoring station to remove the few undesirable elements mixed in with the recyclable materials. The processing chain ends with a screening operation that separates the different products according to their granulometry, and at the end of the process, different types of material are obtained (sand, gravel, gravel.....). The platform has a processing capacity of between 1,000 and 1,500 tonnes per day, and the equipment operates 3 days a week. The platform uses specialized equipment, including a fixed crusher, a fixed screen, a mobile scalper, two loaders and an excavator. In addition, to ensure that the quality of the materials processed is optimal, they carry out sulfate tests and laboratory tests (leaching, percolation, argillosity) and physico-chemical analyses to test the durability of the materials (MicroDevel, Proctor, LosAng) Energy consumption totaled 207 293 MWh for electricity and 114,055 liters for non-road diesel, with photovoltaic energy production of 19 MWh. The reception of waste follows a rigorous process, from the verification of purchase orders through to inspection.

Appendix 4. Details of the visit to the Eiffage platform in Gennevilliers

The platforme de Transit Gennevilliers, established in Gennevilliers under SAS legal status since 2018, occupies 4,500 m² with a team of one to two people. It mainly collects inert materials such as soil, sludge, pebbles and rubble from the construction industry via network, trucks or barges. Around 30 KT of waste is processed annually, with operational capacity limited by surface area. The platform uses an Excel file for traceability, in transition to internal EIFFAGE tools, and measures its efficiency by recycling rate and quality of materials. Reception prices vary from €14/T to €24/T, depending on the analyses and sorting required. It complies with environmental standards, with a water collection system in place. The platform is considering technological and regulatory improvements to reduce its environmental footprint, in particular through massification via the Seine. To ensure the quality of incoming materials, the customer requires prior acceptance and chemical analysis.

Appendix 5. Details of the visit to the CEMEX platform in Gennevilliers

Opening in 2021, the CEMEX platform occupies 3.6 ha and employs 15 people. It is a multi-purpose platform. It recycles construction waste and stores and transports recycled materials. It receives and recycles various types of waste from worksites located an average of 60km away, including reinforced and non-reinforced demolition concrete, pavements and ready-to-use concrete rejects. By 2023, the platform had recycled around 42,000m3 of concrete and 10,000 tonnes of demolition concrete each year, generating gravel (4/22mm) and sand (0/6mm). To ensure the traceability of incoming materials, CEMEX uses a software program called Trinoff and carries out sulfate tests and physico-chemical analyses in an external laboratory for the quality of recycled materials. Currently, the equipment used in this platform is all mobile and includes the electric impact crusher, 4 peels, 3 loaders, scalper, magnetic belt, rock breaker, feed hopper. The platform works with the eco-organization Ecominéro.

Appendix 6. Details of the visit to the ECOSELECT platform at Verne-sur-Sèche

The Ecoselect platform at Verne-sur-Seiche in Brittany covers an area of 1.5 hectares and employs 2 people. Opened in 2022, the platform is associated with several areas of expertise, namely public works, waste recovery and RD. It recycles construction and public works waste, mainly deconstruction waste, rejected concrete and rubble, as well as selling and transporting recycled materials. By 2023, the platform had recycled 150,000 tonnes of demolition and refuse concrete. On arrival, materials are visually checked to ensure that they are not polluted, and sulfate analyses are carried out after each production run to verify the quality of the recycled materials. The platform uses the DAP to trace incoming and outgoing materials. The company is planning to improve the platform by producing mixed aggregates (natural and recycled) and developing the soil sector, in particular by reusing excavated soil for agricultural purposes. The figure below shows photographs of the Ecoselect platform at Verne-sur-Sèche.

Appendix 7. Initiating a mapping project

This appendix presents current data on landfill facilities, the Greater Paris development project and mapping of quarry material resources in the Ile-de-France region.

The map in Fig 26 shows the Greater Paris metropolis, with dots marked in blue. The dots represent sites linked to projects such as Inventons la métropole du Grand Paris and development operations of Metropolitan interest. The data presented allows you to visualize the sites where project work will be carried out. Project planning has been concentrated in the inner suburbs and to the limit of the outer suburbs.

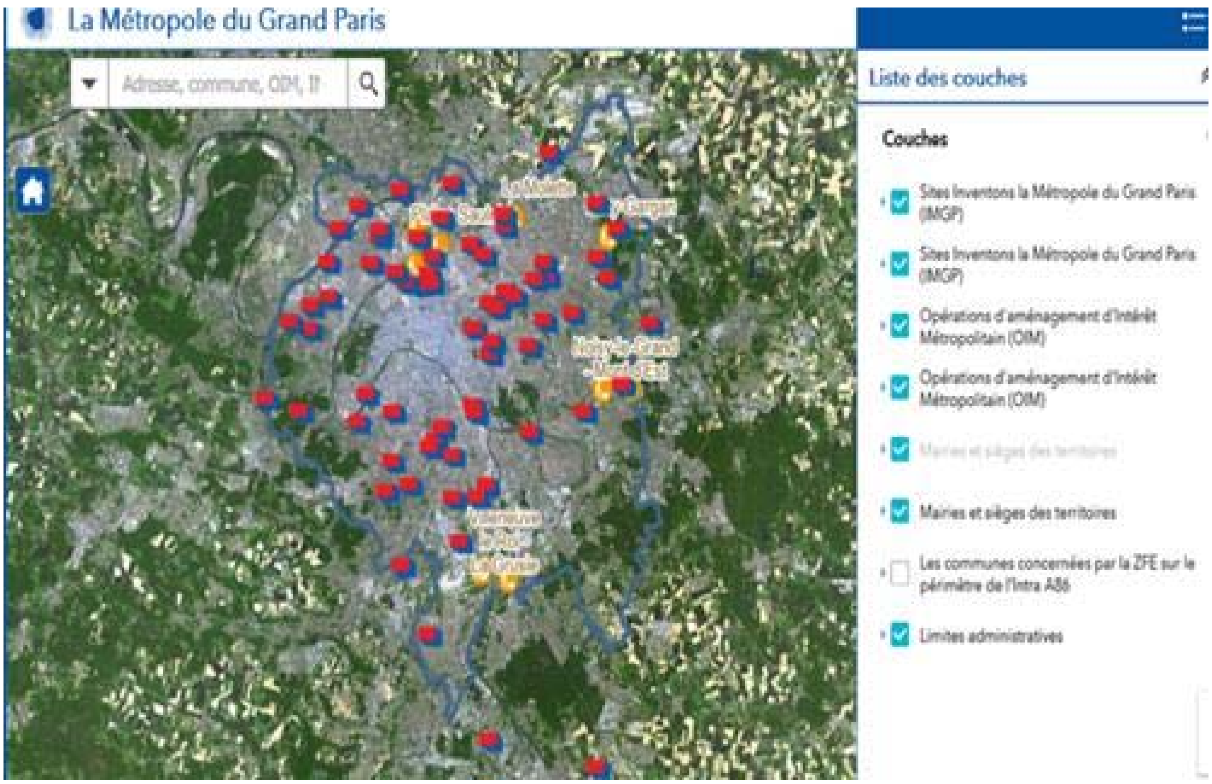


Figure26 Map of the Greater Paris metropolitan area with inventory of work sites.

The map in Fig 27 shows ISDI sites in the Paris region from 2016 to 2021. The brown circles represent ISDI and the green ISDI 3+/n+. Most ISDI sites are located in the outer suburbs, mainly in Seine-et-Marne. More than half of all ISDIs were closed in 2016. At present, ISDIs in the Ile-de-France region have a storage capacity of between 3.5-1.1Mt.

Finally, the map in Fig. 28 represents the mapping of quarry material resources in the Paris region. It shows a colored distribution of geological resources, with yellow, orange and brown colors indicating the different rock types (materials). This map is used for the management and exploitation of natural resources, in particular building materials, in the Ile-de-France region.

The three maps are complementary in terms of mineral materials management. The first map focuses on development projects in the Greater Paris area. For the most part, these development projects are a source of construction waste production. The second map provides a global view of waste storage. It shows inert waste storage capacity and the availability of these ISDIs, whether saturated or not. The third map provides an important geological basis for these development projects, as well as the types of materials produced as a result of quarrying.

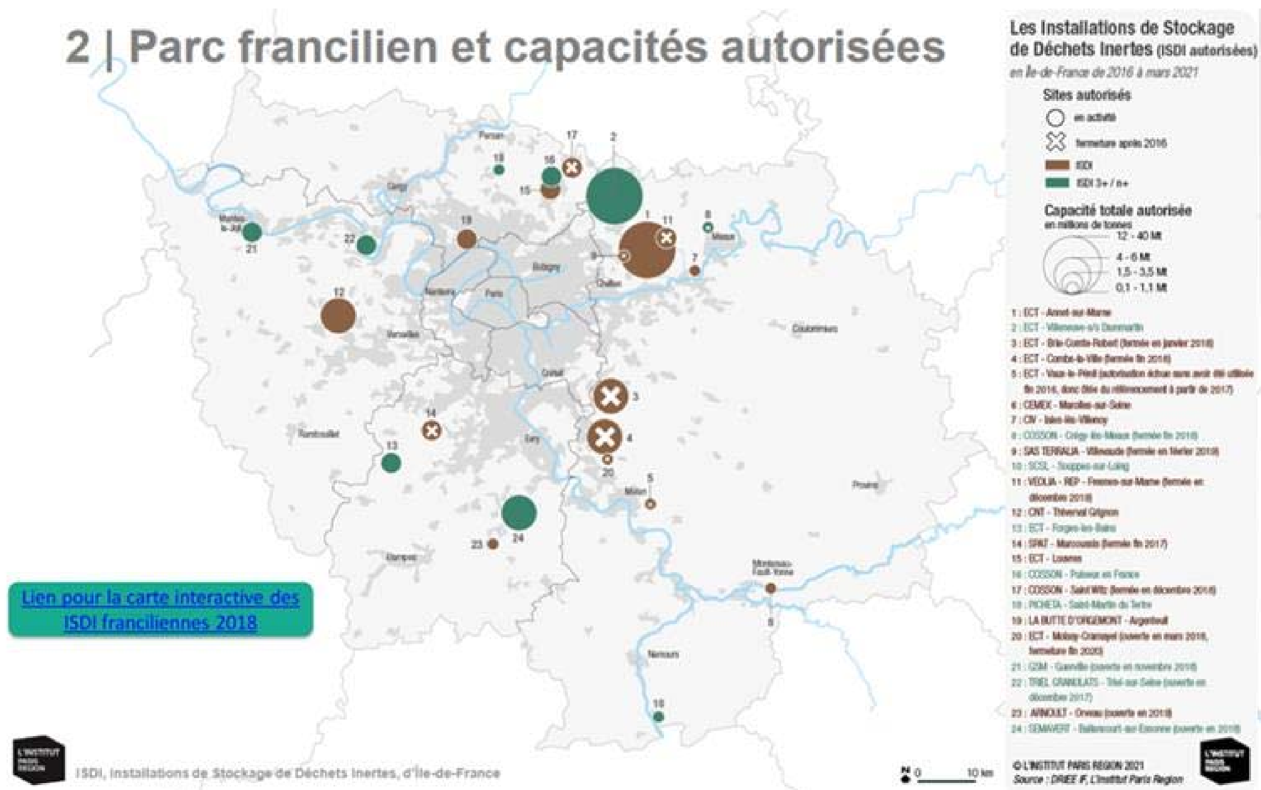


Figure27 Map of the Ile de France region, showing the location of inert waste storage facilities.

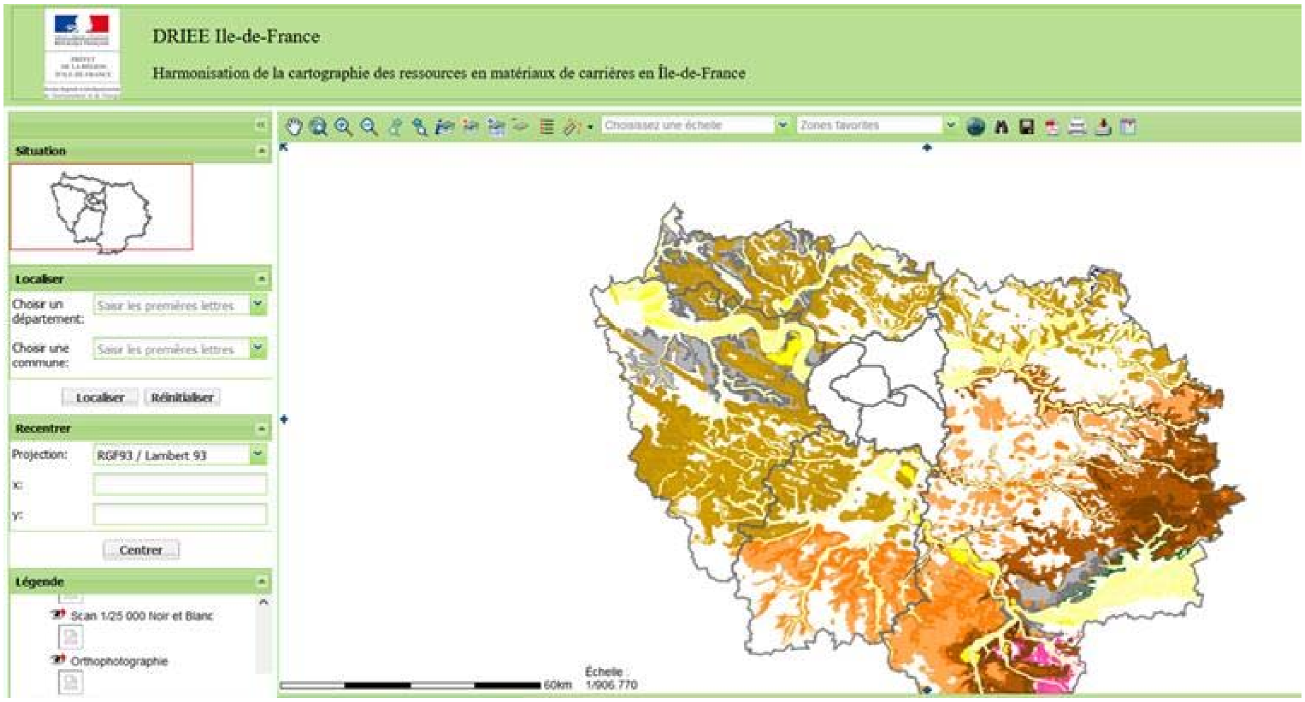


Figure28 Map of the Ile de France region with an inventory of quarries and geological layers present in the region. https://carmen.developpement-durable.gouv.fr/18/HSDC.map

End of Document

ANNEX 2

University Gustave Eiffel
Report year 1 – 2024

MS32 - AXIS 3: ENVIRONMENTAL IMPACT USING INDICATORS – STATE OF THE ART

Assessment of the environmental impact of building construction variants using life cycle analysis. Ranking of impacts.

Co-funded by
the European Union

Document Information

Grant Agreement Number		101082068	Acronym	CIRC-BOOST
Full Title	Sate of the art of Assessment of the environmental impact of building construction variants using life cycle analysis. Ranking of impacts			
Lead Beneficiary				
Responsible Author	Claude Rospars UGE, COSYS			
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Document History

Version	Issue Date	Stage	Description	Contributor
1	October 2024		French version	Malo Langlais, Claude Rospars
2	March 2025		English translation	Claude Rospars

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Table of Contents

List of abbreviations

EC – European Commission

GA – Grant Agreement

WP – working package

1 Executive summary

UGE / COSYS : State of the art and reassessment of the environmental evaluation of experimental Eco construction site (E3S, situated in the suburban areas of Paris).

The research program is structured around the following themes:

• Methodology for quantifying construction and public works flows

• Evaluation and monitoring of circular economy strategies

• Evaluation of solutions on real construction site cases, from an environmental point of view, using ISO 14001,

• Prospective of the circular economy based on the construction of scenarios (construction variants using structural existing parts, more or less recycled concrete aggregate….

This work is part of the understanding of the challenges of the circular economy, which include the challenges of mobilizing waste as a resource, transportation, but also the storage and treatment of waste from deconstruction. Although environmental assessment is highly standardized, mainly via ISO 14xxx, it is difficult to anticipate the impact scores when proposing variants and the importance of the various construction choices, which are still not well understood.

We studied an existing deconstruction-reconstruction site than has been a reserach case from the deconstruction phase (E3S). It is now a living urban zone. The study has been carry out using complete life cycle analysis integrating the deconstruction phases, the management of excavated material and resources and their mobilization within the project (based on real dataset). At each phase, possible variants will have to be evaluated on the basis of the ISO 1400 standard. For example, the following could be considered: reducing the amount of reinforcement and adjusting concrete formulations, using recycled concrete aggregates, reusing reusable structural elements (slabs, columns, wood, etc.). The lifespan of the solutions, including the intended use and the duration of operation (including maintenance) will also form an integral part of the assessment, even if this question of lifespan is not currently regulated.

The objective of this work is to have an approach that prioritizes environmental impact over other criteria, particularly the cost of the project. Fictitious alternative (reconstruction) scenarios can therefore be imagined and evaluated. It is the purpose of this first study, done on the co-district La Valleé (E3S).

Several existing environmental assessment software programs can also be used and compared as part of this study (inhouse program and OpenLCA). Identification of the materials database used on this experimental construction site was used and DIOGEN-CIOGEN database (from AFGC Association Français de Génie Civil) and INIES. The report is then an application of standards and state of the art applied to E3S specifically and propose:

Modelling using LCA tools environemental impact of construction phases and choice of materials, classical construction and experimental building (maximizing recycled concrete materials) and evaluation of scenarios of alternative solutions, with reuse.

2 Introduction

COSYS Laboratory (UGE) is involved in the European CircBoost project, which aims to promote the circular economy in the construction sector and increase its scale of application. The analyse the environmental impact of one of France's first circular economy development projects: the LaVallée eco-district. This project, located in Châtenay-Malabry, began with the deconstruction of the Centrale Supélec campus when the school moved to Saclay in 2017. The conditions for ideal in situ deconstruction were in place: homogeneous buildings in terms of materials and a large surface area (20 ha). In an urban context, and particularly in France, these characteristics are very rarely encountered, making it a perfect testing ground for construction companies and researchers.

A partnership between Eiffage and the Gustave Eiffel University has been set up in the form of the E3S project to create a channel for direct exchange between members of the parties. We revisiting this old research project (2017), focusing on deconstruction, since it produced a significant quantity of recycled concrete aggregates (GBR) that were entirely reused to build the LaVallée eco-district.

The assessment of this project's environmental approach was carried out using the most relevant tool, life cycle assessment (LCA). To take proper account of LaVallée's impact, it was decided to carry out the analysis at two scales: that of a typical building (the subject of my internship) and that of the neighbourhood (on-going research work). For the building, it's a question of creating different construction scenarios to compare, whereas the neighbourhood scale includes, for example, the movements of its users and the management of everyday waste.

To what extent can the comparative life cycle analysis of several building scenarios identify the factors with the greatest influence on the environmental footprint?

Economic studies on building and civil engineering flows exist, and regulatory thresholds exist, but physical data on environmental impacts are scarce in the scientific literature, especially on a neighbourhood scale. What's more, the recycling of old buildings and their reuse on site is rare in development projects. This is the interest of this study, which consists of an analysis of the scientific literature, a presentation of the framework for the work and then the scientific work itself (hypotheses, material and method, presentation of results, discussion).

3 French and Paris context

In France, the building sector is the third biggest emitter of greenhouse gases (Insee, 2022), accounting for 23% of emissions (Ministry of Ecology, 2021). More generally, a building's carbon footprint can be broken down into two categories: embodied carbon and operational carbon. Operational carbon is reduced through improved thermal performance and lower user energy costs. Intrinsic carbon, on the other hand, is the result of a multitude of sources (extraction of raw materials, production of materials, transport, construction, maintenance, end-of-life, etc.), making it difficult to reduce. One of the solutions being considered is the circular economy (CE) (Moncaster et al., 2019) , (Pomponi & Moncaster, 2017) , (F. N. Rasmussen et al., 2018) . French participation in the European CircBoost project, of which this study is a part, investigates one of the main interests of CE for construction: creating new sources of materials to optimize material flows.

In addition, if we are to achieve our goal of "Zero Net Artificialization" (ZAN) by 2050, we need to focus on the building and public works sector. In France, the construction sector is responsible for 70% of the waste produced annually (Chaire EMCU, 2022). The circularization of construction is therefore a necessity from an environmental point of view, but also in terms of land artificialisation. In the Ile-de-France region, over the past 30 years, the proportion of land artificialisation occupied by the extraction of raw materials and the landfilling of waste has more than doubled. Furthermore, the creation of quarries is not counted as artificialisation, notably because they are supposed to be backfilled with materials of similar characteristics to the previous soil, in order to guarantee continuity of use.

The LaVallée eco-district project is part of an approach that addresses both these issues. Soil from nearby construction sites was reclaimed for earthworks, and equipment from the old campus was dismantled for reuse elsewhere. These initiatives are part of the circular economy. What's more, the reuse of GBRs simultaneously fulfils the requirements of both the CE and the ZAN. However, the effect of this approach needs to be put back into perspective in terms of its overall impact on the environment, which is the subject of this first work. At the beginning of this research (T+ 8 months) and innovative work, physical platform was not ready to be studied.

Another interesting point is that this La Vallée eco-district has been fully studied in 2017 before the construction phase. Therefore, decision making processes considered the first LCA analysis made on the project and methodological development had been done to optimise recycled concrete aggregate. Then, our purpose is to have a global view of the real impact, after construction.

4 State of the art

4.1 Presentation and state of research on the concepts used

4.1.1 Life Cycle Assessment (LCA)

In the scientific literature, life cycle assessment (LCA) is considered to be the most appropriate tool for considering all the impacts of an element on the environment. This approach is based on a number of impact indicators, such as GHG emissions, acidification and eutrophication. What's more, the systemic scale of LCA ensures that impacts are not carried over beyond the scope of the study.

The approach, defined by ISO 14040, can be found in figure A. The aim of the first stage is to:

- Determine the most appropriate type of LCA to achieve the study objective
- Define the boundaries of the system in order to precisely define the environmental impacts allocated to it.
- Establish the functional unit for comparing several similar systems

The aim of the following steps is to allocate a series of environmental impacts to the elementary physical flows entering and leaving our system (Guinée et al., 2011) (Hauschild et al., 2017). In practice, the starting point is not elementary flows (oxygen, water) but intermediate flows (producing a tonne of sand for construction, moving a truck) defined by specialists in collaboration with industry. Finally, the LCA process is iterative, meaning that it must be enriched as it is designed, with the help of interpretation.

The version of the European LCA standard that applies to buildings is called EN NF 15804, and it exists in two versions: the +A1 until 2019 and the +A2 which is still in force. The second version is more comprehensive: it includes dozens of additional indicators, and the rules for calculating impacts have been updated. This creates complications and sources of error, as some data, not yet updated, becomes almost unusable. This was one of the factors that most narrowed the scope of the study.

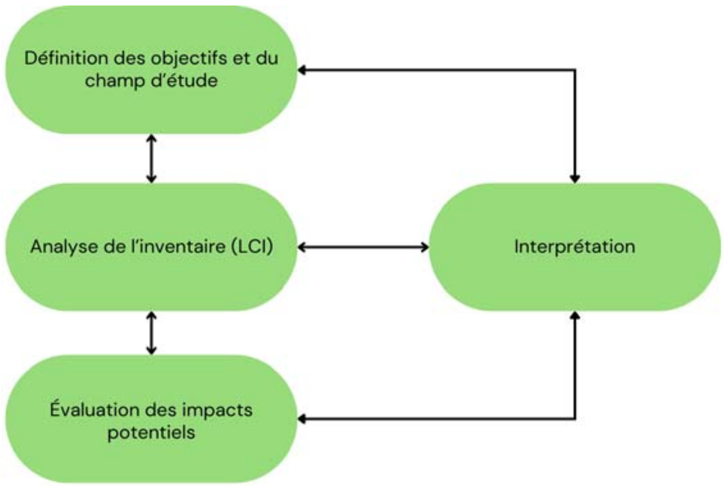


Figure A: ISO 14040 life cycle assessment approach

The various stages and modules of the life cycle are shown in Figure B.

The minimum stages to be considered in an LCA are phases A1-A3, B4, C1-C3 (ILCD, 2010) . In most articles, at least one other phase is zoomed in on, depending on the intended purpose of the building. This assertion is taken to the extreme in the case of MiniCO2 houses, where each version focuses on one of the phases: B5 for the adaptable house and B6 for the passive house, for example (Rasmussen et al., 2020). Since the aim of our study is to compare construction scenarios, we focus on stages A1 to A5. The end-of-life phase is interesting to consider, however, as it allows us to bring the building's life cycle to a close.

The number of development projects in the broad sense of the term that include a cycle analysis is limited, particularly in France, but has been on the increase since the RE2020 *(MTE and Cerema*, 2022)). As a result, much of the scientific literature comes from studies carried out abroad, mainly in Northern Europe. However, the environmental impact of an element depends largely on its geographical location. In fact, characteristics such as the energy mix, provenance and end-of-life options of materials depend on the country and the distance to resources. Our study therefore aims to extend our knowledge of the French case, with the ultimate objective of producing a tool for planners to predict the environmental costs of their scenarios.

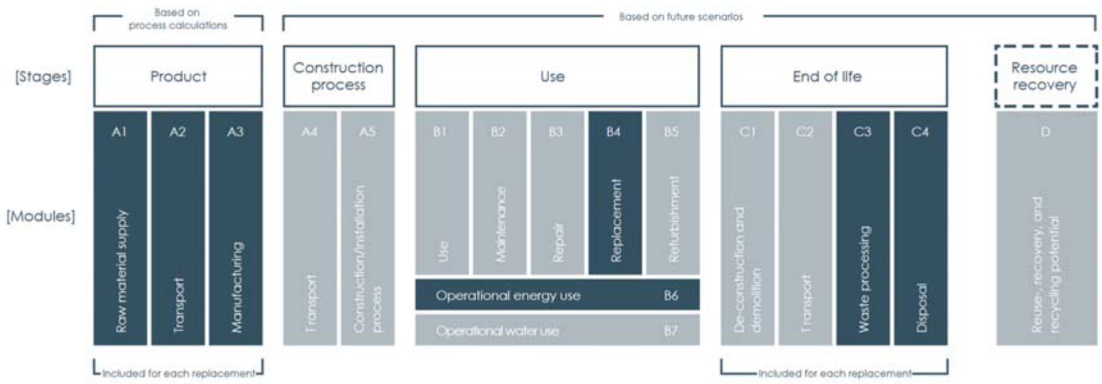


Figure B. Life cycle assessment phases and modules (*Lendager Group*, 2020)

More than a methodology, LCA is a cross-disciplinary field of study combining biologists and structural engineers.

LCA began with the development of products such as plastic bottles. Today, research hubs on this subject are located in Canada, Switzerland, Holland and China in particular. In France, a few dozen researchers are working in this field, the majority in association with their original subject of study (material, structure or layout). From University Gustave Eiffel Anne Ventura (MAST) is interested in the modelling of construction waste treatment and LCA methodology, Adélaïde Feraille (Navier) is concerned with the scale of materials (concrete and steel), Florence Jacquinod and Alexandre Mielniczek (LasTiG) link LCA to BIM / CIM and finally, Bruno Peuportier (2003) is researching the modelling of building energy consumption.

Finally, the real interest of LCA lies in the comparison between several comparable scenarios/systems (same starting hypotheses), so the total value provided is not of primary importance.

4.1.2 The circular economy in construction

According to the French Ministry of Ecology, "the circular economy consists in producing goods and services in a sustainable manner, limiting the consumption and wastage of resources and the production of waste". In the construction industry, this concept is illustrated by the reuse and recycling of materials, design for deconstruction and optimization of material flows. In addition to the articles presented in the introduction, several studies show that the generalization of these practices would have a beneficial impact on the environmental impact of the construction sector (J. L. K. Nußholz et al., 2020) , (Pristerà et al., 2024) , (Ossio et al., 2023) , (Lachat et al., 2021) .

More specifically, a great deal of work has been devoted to reducing the best-known environmental impact of building through circularity: carbon. Indeed, practices such as the use of recycled aggregates or the design of low-carbon materials are being studied from the most microscopic scale to worldwide generalization (J. Nußholz et al., 2023) , (Ding et al., 2023) , (Illankoon & Vithanage, 2023) , (*Chaire EMCU*, 2022) . The present study is fully in line with this approach, as the eco-neighbourhood has been the object of GBR recycling and the creation of "low carbon" roadways (EIFFAGE).

Construction waste management:

As transport plays a major role in the environmental impact of the construction and public works sector, the optimization of construction and demolition (C&D) waste flows upstream and downstream of projects is analyzed.

Several articles examine methods for quantifying and qualifying waste, increase precision on the quantities of materials required, criticize the logistics currently deployed in Europe for waste management and verify the quality of the environmental assessments associated with each practice (Sivashanmugam et al., 2023) , (Fei et al., 2024) , (H & S, 2022) , (Cristóbal et al., 2024) .

Last but not least, innovation in GBR processing, and in particular the transformation of waste materials into high-quality cementitious materials, is a key area of research. Studies in this area show how GBR processes can be optimized to obtain concrete construction materials of equivalent or higher quality than their conventional counterparts, while reducing pressure on natural resources (Rodriguez-Morales et al., 2024) , (Wu et al., 2024) , (Abedin Khan et al., 2024) .

An LCA, and then what?

LCA is the indispensable foundation of eco-design, enabling us to predict the potential environmental consequences of the solutions we are considering. But for these predictions to be useful, they need to be robust and accurate. LCA research is therefore in full swing, with the aim of producing reliable models.

First of all, since LCA is an agglomeration of microscopic elements, establishing systems as large as neighbourhoods is still difficult, and methods for assessing their impact even more so. Several studies are focusing on adapting existing LCA methodologies and better characterizing the elements belonging to the system (Mielniczek et al., 2023) , (Peuportier & Roux, 2016) , (Rayegan et al., 2024) , (Roux et al., 2017) . This aspect corresponds more precisely to the subject of the second trainee.

BIM (Building Information Modelling):

BIM is a valuable tool for LCA as it allows accurate and comprehensive project information to be defined and shared. Work is being done to couple it with construction, design for deconstruction and the circular economy in construction (F. Rasmussen et al., 2019) , (Aziminezhad & Taherkhani, 2023) , (Xue et al., 2021) .

4.2 Impact of the environmental approach on a building

4.2.1 Regulations

Several regulations need to be considered to understand how environmental assessments work in construction.

The method for carrying out a life cycle assessment is standardized at international level with ISO 14040 and ISO 14044, which respectively define the theoretical and practical aspects to be followed.

Standard NF EN 15804 defines methods for calculating impact indicators for construction products, and is based on environmental and health declaration sheets (FDES). The INIES and DIOGEN databases contain FDES for versions +A1 and +A2 of the standard, and the difficulties this poses will be explained below.

Since the RE2020 standard was adopted in 2022, all new buildings must be fitted with an LCA. The normative framework has set values deemed acceptable for thresholds, but the current state of scientific research, particularly in France, is not in a position to provide precise justification for the choices made. On the other hand, this decision does provide access to French LCA data, which is vital for the advancement of research.

Given the importance in the literature of taking the circular economy into account to reduce the impact of building and civil engineering, some researchers are proposing to integrate it into impact indicators for LCA (Peuportier, B. (2023)).

5 Assessment of environmental impact of building construction variants

Our first objective was to take stock of the data contained in the files submitted by Eiffage on the LaVallée eco-neighbourhood, and to identify potential topics for research into environmental impact analysis. The dossier contained only information on the deconstruction of the Centrale campus, but nothing on the construction of the eco-neighbourhood

At the same time, I studied the information published on the construction of the LaVallée eco-district, deepened my knowledge of French and European regulations on life-cycle assessment, and reviewed the state of the art on LCA in the world and in France, eco-districts and the impact of buildings and construction waste on the environment.

Following this primary work of clearing out the subject of study, Otavio and I divided up the work as follows: he dealt with the scale of the district and I with that of the building. This division enabled us to work independently on two complementary parts.

The next step was to produce a first approximation of the building model. Indeed, after realizing that we didn't have the necessary data to quantify the impact of the buildings (apart from floor area) in the eco-district, I turned to modelling to obtain them.

To find out what was important to model, I relied on the availability of environmental records in the **DIOGEN and INIES databases,** and on the orders of magnitude of the impacts of building components. Unsurprisingly, structural work plays an important role, so I tried to estimate the quantities of reinforced concrete used.

Finally, we modelled several construction scenarios represented by different systems. These are presented in the following sections. I compared these scenarios by creating an Excel LCA spreadsheet and integrating these scenarios. I refined and verified my results live by integrating representations into my sheet that made any significant differences in orders of magnitude immediately visible.

5.1 Case studies

The aim of this section is to present the LaVallée development project, analyse its material flows and, finally, detail the assumptions made to create the building model for plot A. The flows considered are those that play a role in my study, notably excluding land management and reuse, neither of which had any connection with the eco-district buildings. This research work, like this model, is a first sketch, so the aim is to obtain a working basis. The model is therefore partial in terms of the construction elements considered (structures) and approximate in terms of material quantities. This methodological transparency, often lacking in the LCA field, will enable me to justify my reasoning and pass on my progress to the next people working on this project.

5.1.1 The La Vallée eco-district

The LaVallée project, located in Châtenay-Malabry, Hauts-de-Seine, is an eco-district extending over the former École Centrale site, covering some 20 hectares. Developed by France's first SEMOP (Société d'Économie Mixte à Opération Unique), the project aims to create a sustainable and innovative urban development district. The SEMOP Châtenay-Malabry Parc-Centrale is made up of Eiffage Aménagement (50%), the town of Châtenay-Malabry (34%) and Caisse des Dépôts. To place the public order, the deconstruction lots were divided into five similar parts, shared between several companies, the construction was also allotted and a concession for Eiffage Aménagement was agreed.

Image 1: Geoportail map

In quantitative terms, LaVallée comprises 213,000 m² of building space. This area will be used to build 2,200 housing units, including 372 social housing units, 36,500 m² of office space, 15,000 m² of retail space, a middle school for 700 pupils, a school complex with 22 classes, a nursery for 60 children, a one-hectare urban farm, and around 450 public parking spaces (*Press Kit 2 Eiffage*, 2018). In addition, the project includes around 8.5 hectares of public and private green spaces.

Image 2: Eco-district presentation model

5.1.2 Material flows

We're going to focus on the main flow of the project and therefore of this study: the trajectory of concrete between the deconstruction of the campus and the construction of the eco-district.

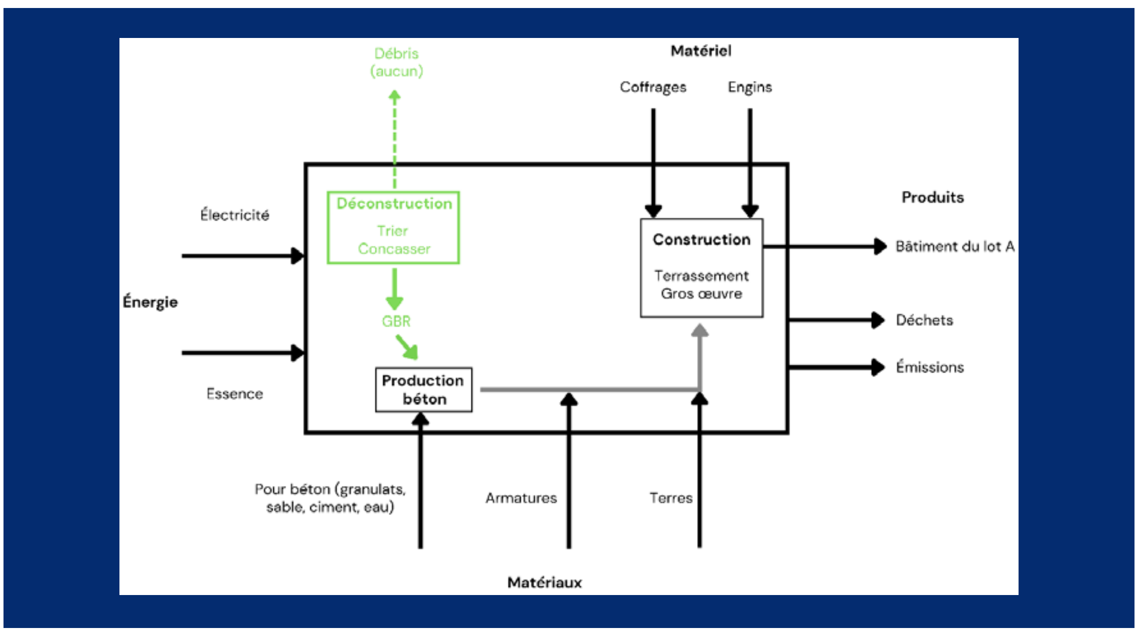
The existing École Centrale buildings, totalling 85,000 m², were completely demolished to make way for the new district. Following this deconstruction, 120,000 tonnes of rubble were recovered after sorting and crushing to finally obtain 60,000 to 65,000 cubic meters of recycled concrete aggregates (*DP CHATENAY-MALABRY*, 2021). These GBR can be broken down into two particle size families with different uses: fines (equivalent to sand) and gravel. The dossier submitted by Eiffage on the deconstruction operation and the eco-neighbourhood provides details of the proportions of each category. At E3S, gravel (type 4/22) was used in the concrete to the tune of 30% of total aggregates. This percentage was the maximum integration value for GBR legal at the time. This percentage was subsequently raised, thanks in particular to the project's inclusion in the E+C- label, which was subsequently transformed into RE2020. As for fines, we have no certainty about their use in concrete. In fact, this process has not yet been developed on an industrial scale, as it is not yet used on recycling platforms (Cf. Visit to Gennevilliers platform, CEMEX). This is due to the highly variable quality of the concrete recovered from recycling platforms. On site, however, the concrete of the buildings is particularly homogeneous, so it makes sense to take into account the insertion of fines in the new concrete.

The remainder (two-thirds[1]) of the aggregates are not compatible with such use, and are therefore put to road use. This is the most widespread area of GBR reuse. A process to produce more material for concrete would be technically feasible (crushing and sorting 0/31.5 blocks, for example), but is not desirable. In fact, GBR is already used in its entirety on the market, and the energy required for processing (machine operation) must be minimized. Finally, the production of natural aggregates in France was 314 Mt in 2017 and only around 100 Mt for recycled aggregates (*UNICEM Statistics*, 2017), (*Enquête sur les déchets et déblais produits par l'activité BTP en 2014 (EDD 2014)* | *Données et études statistiques*). GBR production is therefore not sufficient to cover the needs of BTP and is limited by the amount of deconstruction. This is satisfactory, as the aim is to waste as few resources as possible and not to create a market for recycled materials.

5.1.3 Modelling the "Lot A building"

The following section defines the limits (in the LCA sense) of the system studied, and details the physical modelling of the building (quantity of materials, etc.).

First of all, the system studied is illustrated in figure C. The large rectangle illustrates the limits of the system, and arrows linked to this rectangle apply to everything inside it, whereas arrows linked to a single sub-are only valid for it. For example, electricity is used both during deconstruction and production, and is therefore linked to the large rectangle, whereas formwork is a material that is only counted in the phase to which it is linked: construction. This method of representation makes it possible to clearly set out the system's attribution assumptions, so as to be totally transparent about what is accounted for. It also makes it possible to compare systems clearly, which will be done in the next section on construction scenarios.



[1] *A large-scale circular economy demonstrator in a 21st-century eco-neighborhood, n.d.*

Figure C: Delimitation of the "Lot A building" system (in French)

Building A in the LaVallée eco-neighbourhood is thus produced in the conventional way, with one exception. Materials, equipment and energy are brought in, and recycled concrete aggregates sorted and recycled on site take the place of natural aggregates in the concrete formulation. The benefits of this application to the construction of the circular economy are twofold: the transportation of debris is avoided[2] and the quantity of aggregates and sand to be imported is reduced. It is this real impact that is studied in this study. As we only have the quantity of GBR (120,000 t) produced on the entire site, I have assumed that the quantity of debris avoided is proportional to the SDP. In concrete terms: 120,000 t for 213,000 m² of floor area gives 1254t for our building (whose characteristics are described in the following paragraph).

Figure C details the production and construction part of the building's life cycle, corresponding to stages A1 to A5 of the LCA. The other stage considered in the study is the end-of-life phase (C1-C4), on the assumption that it has the same impact as the earthworks and construction phases (A3-A5) combined. The benefits of including this stage will be presented in the section on construction scenarios. It's a first approximation that gives an order of magnitude for the elements that really have an impact on the overall environmental balance.

Secondly, the building chosen is located on image 3 and is part of the construction lot completed in the first phase of the development project. This choice was based on several considerations:

- The building is architecturally homogeneous with the rest of the ZAC, which makes it possible to extrapolate the results to obtain the impact of the eco-district's buildings.
- The building exists, which makes it easier to study and thus improves the accuracy of the study. Moreover, obtaining quality data proved to be a recurring problem in this work.

[2] According to the briefing note on artificialisation (*Chaire EMCU*, 2022), the limit of circularity is the increase in building density, which is the case here.

Image 3: Eco-district project with Building A highlighted

- The building has been modelled on BIM (see Image 4) and has been the subject of study by two EIVP research professors, so I was hoping to be able to draw up a detailed model of my building.
- A link with the concatenation of neighbourhood BIMs or CIMs cannot be ruled out for the rest of the study. Nevertheless, a partnership with the owner SEMOP is necessary.

Image 4: Concatenation of BIM phase 1 and bât. A highlighted

As for the building itself, its appearance can be seen in image 5, taken from Eiffage's 3D tour of the district.

Image 5: Digital mock-up of Lot A building under study

It's a modern multi-family dwelling, R+3, in reinforced concrete structure with an extensive green roof. There are cellars in the basement, which were not considered in this preliminary study. The following model was derived from this real building:

Quantitative building characteristics	
Ceiling height (m)	2,5
Number of floors	4
Height (m)	11
Width (m)	21
Length (m)	26,5
Floor area (m²)	556,5
Gross floor area (m²)	2226

Figure D: Table of the main quantitative characteristics of the modelled building

- The building can be likened to a right-angled block, the height of which corresponds to the 4 storeys with an assumed 2.5 m ceiling height and an additional 1 m corresponding to the acroterion.
- Length and width were approximated on a scaled map of the project.
- The total length of the walls was used to determine the quantities of materials required. Details of the calculations can be found in the following section. A simple model of the building's interior, with 6 apartments and one stairwell per floor, is shown in Figure E.

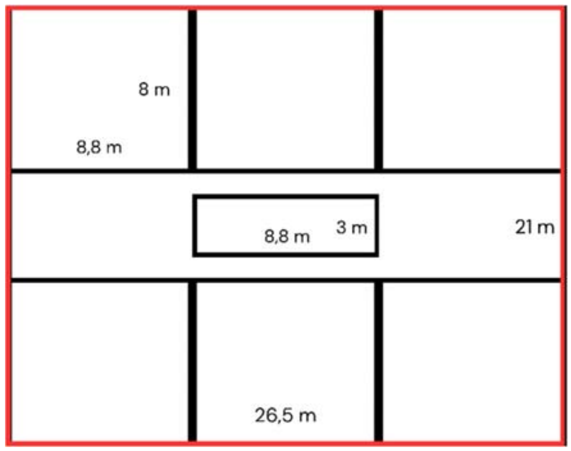


Figure E: Modelling each floor of the building

5.2 Definition of the construction scenario

This section is divided into two parts: firstly, the justification for the scenarios chosen, and secondly, details of the quantities of materials and their method of acquisition.

We have two main scenarios and one variant. The aim of this work is to estimate the real gain in environmental impact of on-site aggregate recycling, so we decided to compare a "conventional" building with a "recycled" one. The recycled model has already been presented at the beginning of the section "Modelling the building of lot A". In the conventional model, Centrale's rubble was transported in its entirety to the CEMEX recycling centre in Gennevilliers, 27 km away.

We visit this recycling platform for construction and public works waste and learn about the issues it faces both on the ground and in the future. Most of the waste is transported by barge, but given the location of the eco-neighbourhood, it was decided to stick to a road-only modal scenario for the sake of simplicity and realism.

In the study, all components are transported by 22 t trucks, and the distances from the production sites are detailed in image 6. They were found in the "Panorama régional des granulats" *(DRIEE et al.*, 2017). Where nothing was found, the usual value of 50 km was chosen.

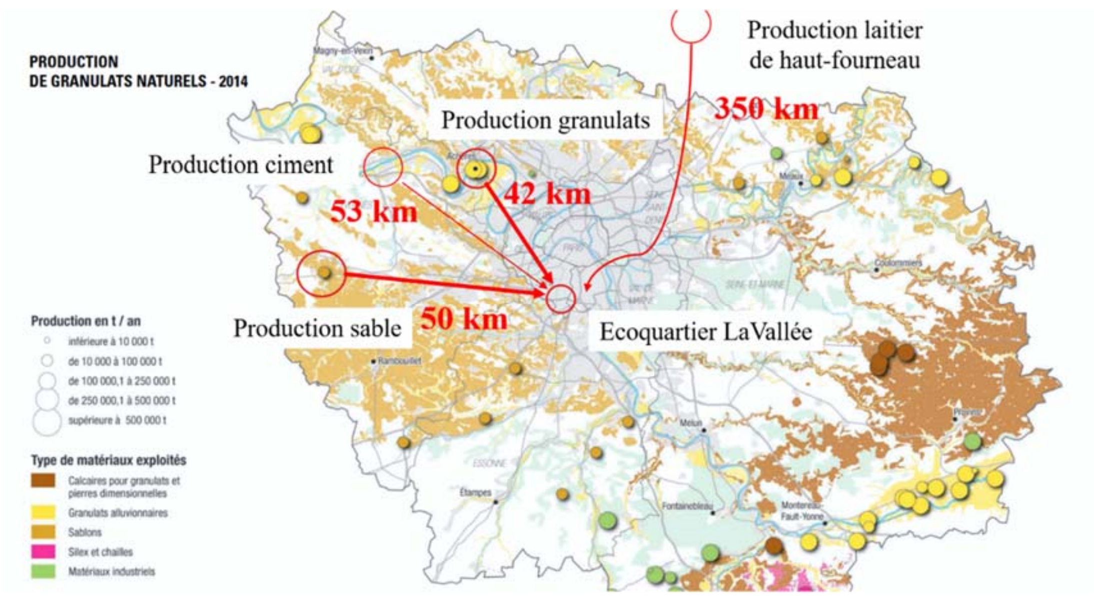


Image 6: Map of concrete component production sites in the Paris region

The third scenario is the "Alternative" variant, which represents a wood-raw earth building as conceived in E. Moesch's study, of which this work represents the continuation.

In this scenario, the GBRs were entirely reused in the new roadway, which would still be possible according to this study, in which the aggregates requirement modelled for the roadway is 175,000 t and the total quantity of aggregates modelled is 171,000 t.

A schematic comparison of the three systems can be found in Appendix 1. Insulation consists of rockwool for the concrete scenarios and wood fibre for the raw-earth-wood scenario.

Quantifying material flows posed a problem for us, given the scarcity of information gleaned from the project. The aim was obviously not to obtain an ultra-precise estimate, but to have an order of magnitude of the quantity of materials present in the building to determine the embodied carbon. As I had no idea of the orders of magnitude of reinforced concrete to be applied, and had no projects to compare, I searched the scientific literature for a suitable method.

The study carried out by (García de Soto et al., 2014) uses linear regression and neural network techniques to predictively model the quantities of concrete, reinforcement and formwork required to erect a multi-family dwelling. Although the aim of this study was to accurately anticipate financial costs, I was able to use it because the method for obtaining costs is also based on "construction material quantities" (CMQ).

The study is based on the wall/floor area ratio to qualify a building, but doesn't specify this criterion, so we don't know whether interior walls are included or not.

Including them in the definition brought a much more credible result around 1000 m3 of concrete. That's why I simply needed to model the interior of the building in Figure E and obtained a ratio of 0.66.

In addition, the study proposed two ways of establishing the quantities of materials: by graphical search (Cf. Image 7) or through the values of the coefficients of the linear regressions. Then calculated and checked their deviation, and finally used their interpolation in the rest of the study (see Figure F).

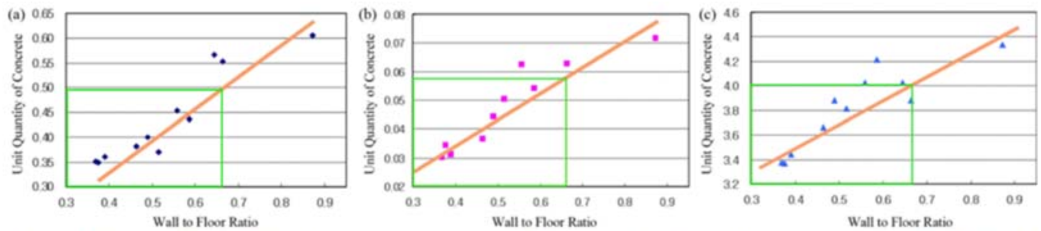


Fig. 9. Scatter Diagram on Unit Quantity of Structure Frame in Typical Upper Floor related to Wall to Floor Ratio: (a) Wall to Floor Ratio and Unit Quantity of Concrete, (b) Wall to Floor Ratio and Unit Quantity of Rebar, (c) Wall to Floor Ratio and Unit Quantity of Formwork

Image 7: Curves for determining quantities of materials per square metre

Element	Ratios	Curve	Function	Deviation	Total
Concrete	m3/m² (m3/m²)	0,5	0,51	2,00%	1124 m3
Armature	t/m²	0,058	0,063	8,62%	135 t
Formwork	m²/m²	4	4,05	1,25%	8964 m²

Figure F: Determining ratios of quantities of structural elements per square meter

Then, to separate concrete in which 30% of the aggregates and sand are replaced by GBR from conventional concrete, I used the DIOGEN data sheet for C35 concrete. This sheet details the composition of a cubic meter of concrete. In addition, recycled concrete was studied as part of the Recybéton project (*Ifsttar*, 2018) and it was concluded that too much recycled concrete aggregate could necessitate increasing the cement fraction in the mix. This is because GBRs have a layer of cured cement on their surface, which impairs the homogeneity of the mix by absorbing some of the admixture. Up to 30% sand substitution, there is no need to increase the cement content of the mix.

Finally, the quantities of materials for the alternative scenario were taken from the study estimated by E. Moesch, the same for insulation.

As promised in the previous section, the idea behind integrating the end-of-life phase into the study is not to compare buildings alone, but rather economic and technical construction models. For the classic scenario, the debris to be disposed of is therefore counted a second time.

5.3 LCA analysis

The file used to carry out the LCA is an Excel spreadsheet broken down into 4 phases and 3 parts per phase. The 4 phases are those of the LCA: A1-A3 production, A4-A5 implementation, C1-C4 end-of-life and finally the total. The three tables are side-by-side, but should be on different spreadsheets for greater clarity and practicality, and therefore precision (Cf. Julien Cravero). The first table is for primary data, the second for process modeling and the last for final calculations. The general layout can be seen in Image 8.

The various assumptions and definitions of the intermediate systems are listed in the green tables in the file. In this way, the person continuing this research will be able to start from this base if necessary and complete the model as easily as possible. The purpose of this report is also to clarify the choices made so that the transition of knowledge can take place efficiently.

In the end, Open LCA was not used to transmit these results, as the elements needed to use it were missing. Firstly, it is a reference database, the best-known and most widely used being ecoinvent. The DIOGEN database targets French structural elements and is not incorporated into OpenLCA, so it cannot be used, nor can INIES. Even if this were the case, would still be missing the European standard NF EN 15804 for calculating impacts in France. The adaptation was developed by Tiffany Desbois. I was advised on this part by Julien Cravero, research engineer at Les Ponts and creator of the CIOGEN tool. It was thanks to this similar tool, developed for the world of engineering structures, that I was able to obtain the missing data for my LCA.

This free-access Excel file gives the environmental impacts of machinery, transport and wood. The rest of the data comes from DIOGEN, INIES and OpenLCA's free ELCD reference database.

The problem I had to face was the compatibility of data from extremely diverse sources. Some irreplaceable data, such as GBR and transport, were not calculated using the same version of NF EN 15804 (+A1 and +A2). Fortunately, two indicators have not been changed: global warming (expressed in kg of CO2 equivalent) and freshwater eutrophication (expressed in kg of (PO4)3- equivalent). I have therefore chosen to base my calculations on these two indicators, even though eutrophication is generally used to assess pollution from fields and factories. Unlike climate change potential, eutrophication has a localized impact. As the geographical factor has not yet been included in this study, the framework for studying this indicator is not complete. Nonetheless, it enables us to improve the robustness of our results and to compare them with climate change.

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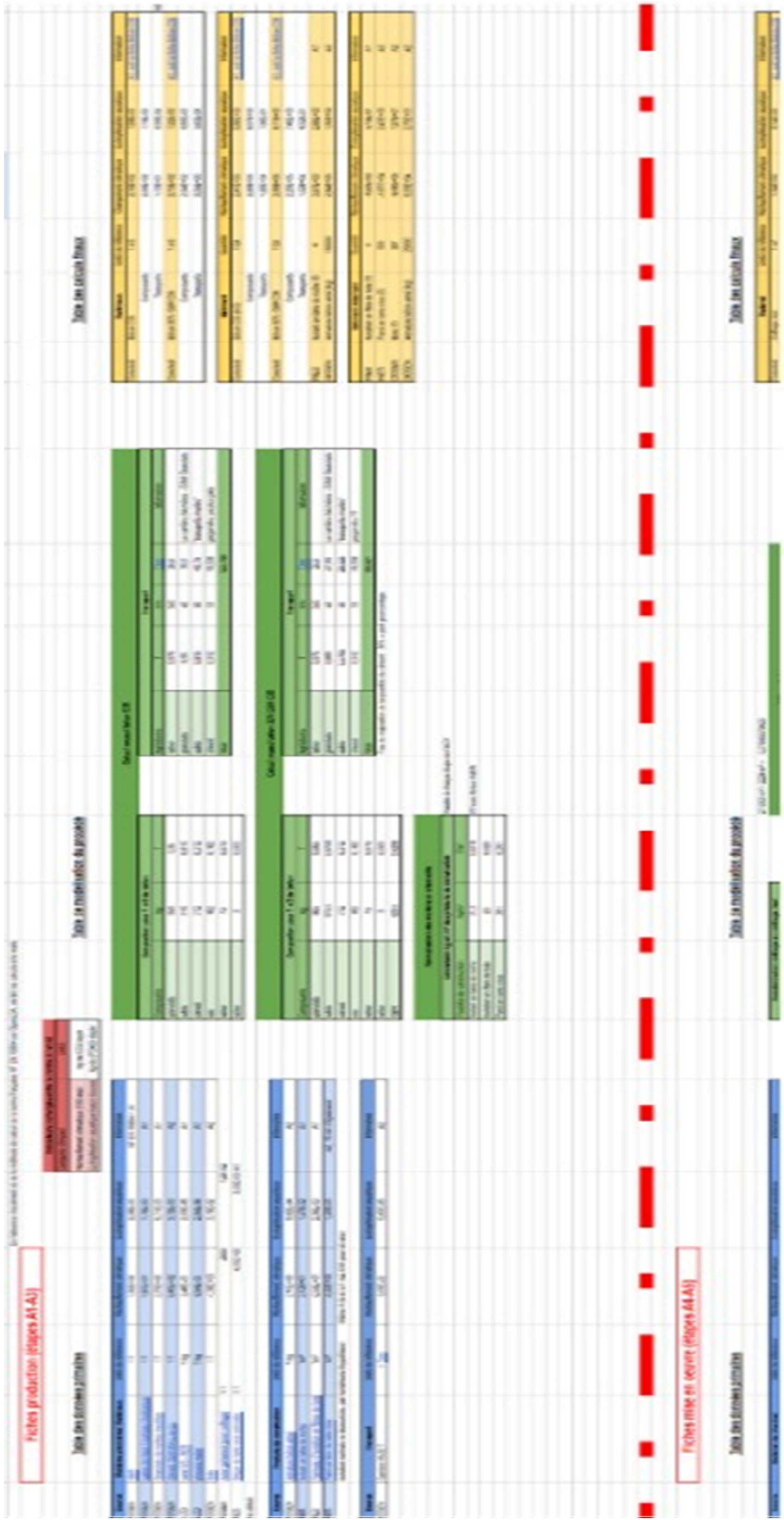


Image 8: Structure of the building LCA tool

5.4 Results presentations and discussion

The results of estimating the real environmental impact of in situ recycling are presented in a series of graphs. The Classic and Recycled scenarios are compared.

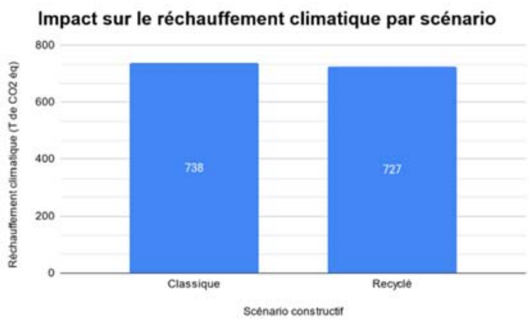


Figure G: Global warming impact by construction scenario

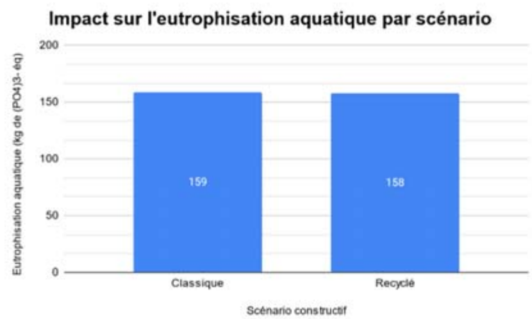


Figure H: Impact on aquatic eutrophication by construction scenario

The results, broken down by LCA phase, are presented below:

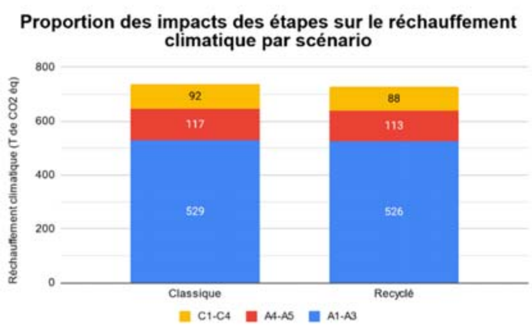


Figure I: Impact on global warming by phase

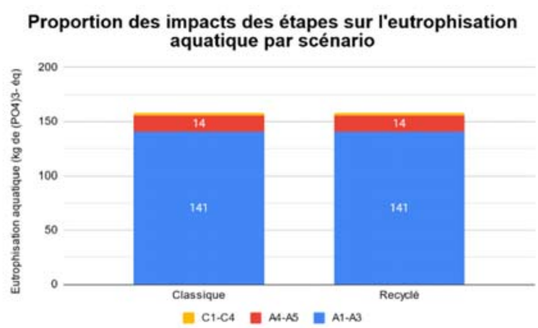


Figure J: Impact on aquatic eutrophication by phase

The difference between the total impacts of the two scenarios is 1.5% and 0.63% for global warming and aquatic eutrophication respectively.

Discussion

The difference between the two scenarios is minimal on these two indicators, but perhaps if resource consumption were included, the difference would be greater.

To check the order of magnitude, I compared the carbon savings for transport in E. Moesch's study and in this one. I obtained a difference of 51%, and whereas she found 52.5%, at least for transport, the study is therefore plausible. Furthermore, the figure of 600 tonnes of CO2 saved for the whole district is in the Eiffage press kit. This figure is taken from the study by E. Moesch.

On the total value, although secondary as explained in the section on LCA, the usual high value is 600 kg of CO2 equivalent per m² (*OBJECTIF CLIMAT - Pourquoi se loger pour 350 kg de CO2 par an?*, 2013) i.e. 1335 t for our building.

We are at 55% of the expected total. In France, the construction stage usually accounts for 60% of the total, and energy consumption for 40% (Charraire F., 2023). Energy consumption during use (stage B1-B6) is not included in the study, so the order of magnitude seems correct.

Now, in Figures I and J, the A1-A3 part has the greatest impact, and the other two are of the same order of magnitude. This similarity is to be expected, given that the definition of stage C1-C4 is based on that of A1-A3. Despite the emphasis on comparing circular economy practices, the difference in impact between the implementation and end-of-life phases is 3.8% for global warming and 0 for eutrophication.

With these results, important hypotheses emerge: this is what we call screening. As LCA is an iterative process, it is appropriate to return to the elements that have had the greatest impact. Here, we're talking about phase A1-A3, and the contributions of each component are shown in Figures K and L.

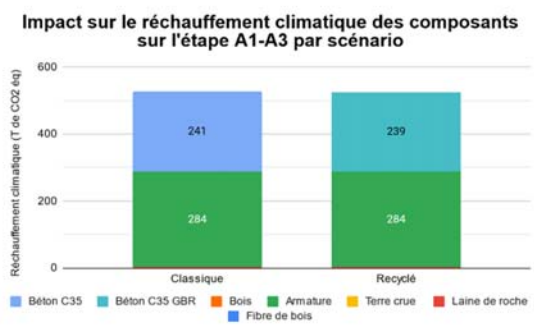


Figure K: Impact of components on global warming

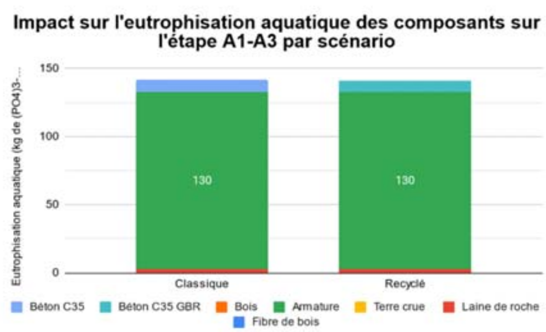


Figure L: Impact of components on aquatic eutrophication

The observations are as follows:

- Steel has the biggest impact on both indicators.
- Concrete has the second highest impact on global warming, on a par with steel. This observation corroborates with the dossier on cement (*FEBELCEM*, 2005) presenting the elements with the greatest weight on the energy balances of Belgian reinforced concrete.
- Conventional concrete and 30% GBR show almost no difference in impact.
- Concrete has little impact on eutrophication.

In conclusion, precise quantification of the flows of these two materials should be encouraged.

5.5 Variants – fictive scenarios

After noting that the attempt to recycle the recycled scenario compared with the conventional scenario showed no significant gain on its own on these two indicators, it was decided to continue the study by exploring more reductive avenues.

The wood-raw earth variant presented in the construction scenarios section promotes a local type of construction using materials that are less damaging to the planet. This scenario was introduced in E. Moesch's study, and I felt it was appropriate to include it for two reasons: firstly, it enabled this new study to be placed directly in the continuity of the previous one, facilitating the reuse of this work; and secondly, it is representative of current alternative constructive scenarios. The structure consists of wood and steel, while the non-load-bearing walls are made of compressed earth bricks and extruded clay panels. The appearance of a mud house can be seen in Image 9.

Insulation installation was also included in the study, to broaden the range of materials considered and compare bio-based and conventional solutions.

Two other main variants were considered but not retained in this study. The first was to keep the existing buildings in their entirety, or just the structure, and integrate them into the eco-district project. The reconfiguration of existing buildings is a widespread practice in the construction industry, saving on the structural part of the project. It would have been necessary to adapt this possibility to the development project in order to realistically reduce the surface area to be built. This would have been possible because we have maps of the old campus and the new eco-neighbourhood, with the Halle des tilleuls as a reference point for superimposing them. We would also have had to define the uses of these buildings and quantify the impact of the renovations. Moreover, asbestos removal is not an issue, since it is carried out even in the event of demolition. This avenue was not pursued here because it was not central to the study. However, it is worth studying.

Image 9: Example of a timber-earth house (source: Germain HERRIAU, photographer)

The second variant involves comparing different formulations of building materials. This would involve varying the quantities as well as the nature of the building components. For example, the French cement industry is seeking to develop solutions that emit much lower levels of greenhouse gases (see Figure M). Steel also plays an important role, as we saw in the previous section.

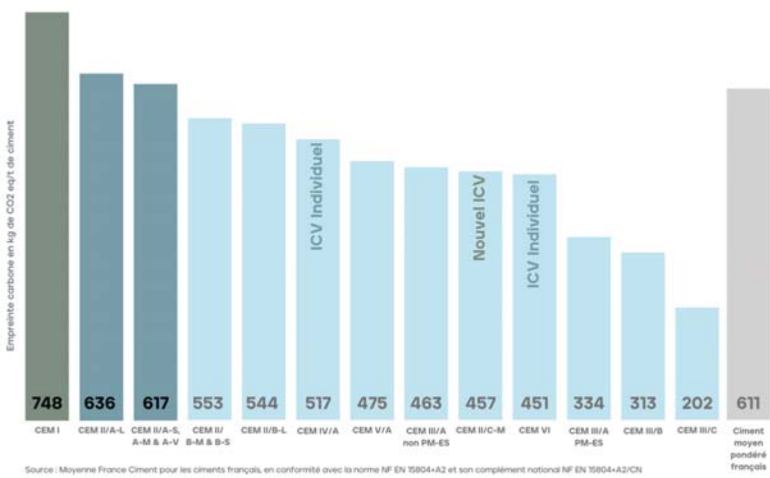


Figure M: Comparison of the impact of successive generations of cement (CO2 eq/t)

However, to create realistic scenarios of material proportions, it's necessary to partner with a company or an expert in the field.

Finally, a third possibility, and one that will certainly be developed in the short term in the remainder of this study, is to transpose the concept to other urban contexts, such as the city, where the density of the existing environment makes it impossible to recycle in situ.

The above list of potentially beneficial scenarios is by no means exhaustive, but it does provide a glimpse of the ultimate aim of this research. The aim is to apply these solutions to a concrete development case, making it a playground of sorts, to draw direct comparisons. Ultimately, this would provide planners and other professionals with the environmental costs of different scenarios at the design stage.

5.5.1 Results presentation of variants

The results of the environmental impact assessment of the alternative scenario are presented in a series of graphs. The three scenarios are compared.

Figures N and O show the absolute results, while Figures P and Q show the impact of the various phases on the balance.

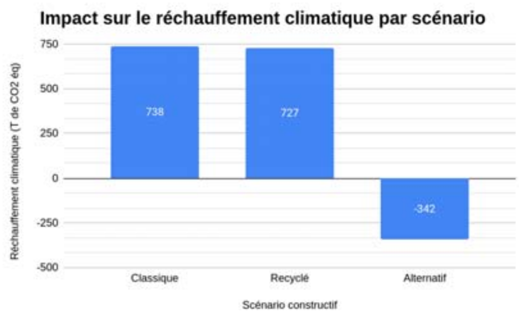


Figure N: Global warming impact by construction scenario

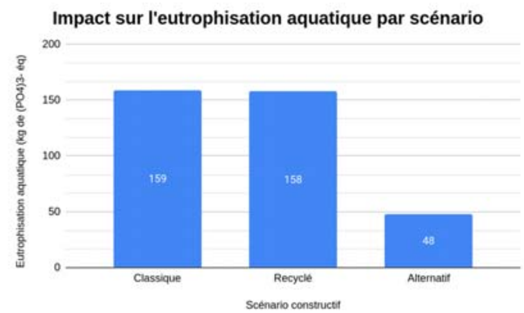


Figure O: Impact on aquatic eutrophication by construction scenario

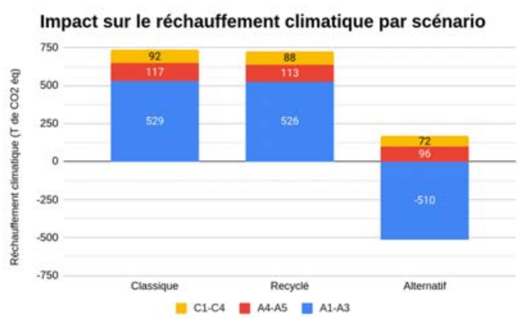


Figure P: Impact on global warming by phase

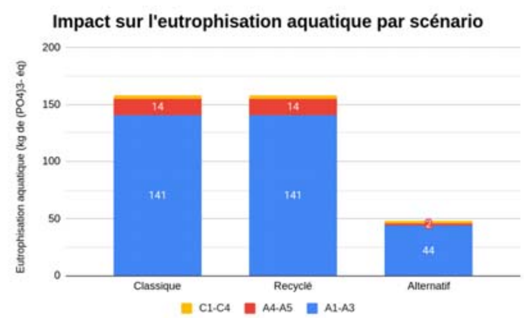


Figure Q: Impact on aquatic eutrophication by phase

For both indicators, the alternative scenario emits much less and even captures the equivalent CO2.

The main conclusions obtained with the two concrete scenarios also apply to the Alternative scenario: production plays a prominent role, and the magnitude of the other two phases is similar. The main difference is due to wood, considered by the designers of its product sheet to have a negative impact on the balance sheet. This assumption imposes a minimum lifespan for the tree before it is cut down, as well as a controlled harvesting of forests. What this solution achieves on paper therefore depends directly on the territorial policies in place and tends not to be generalizable. The hypothesis therefore needs to be criticized and justified by further knowledge on the subject.

The other assumptions impacting the implementation and end-of-life phases are shown following diagram and are illustrated by the most important parts of some indicators.

Comparison of the three construction systems

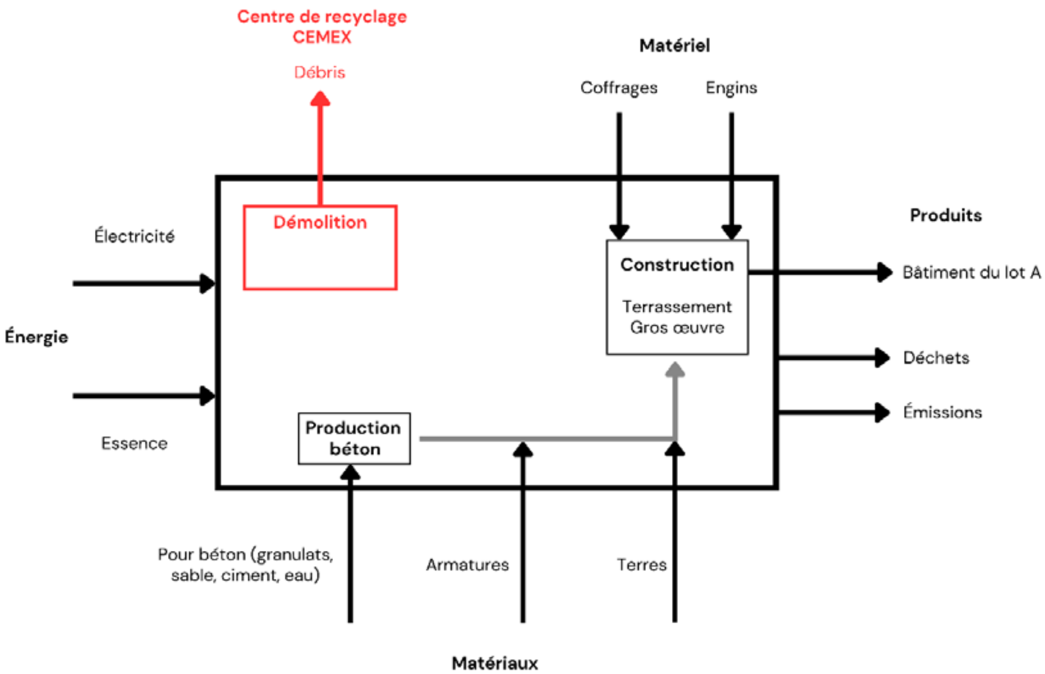


Figure: classic scenario

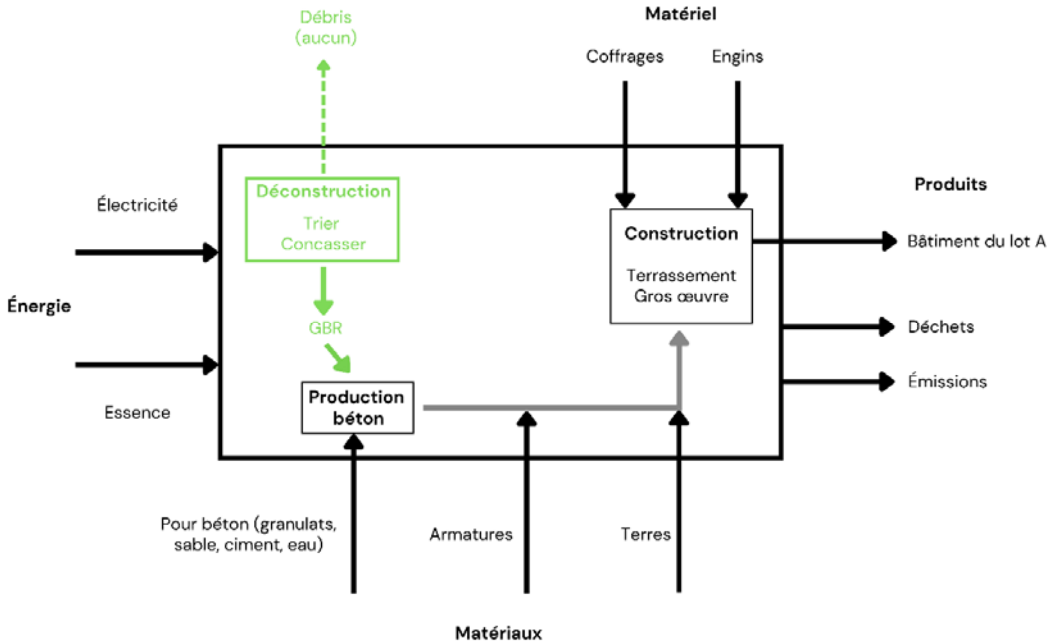


Figure: recycled or realistic scenario

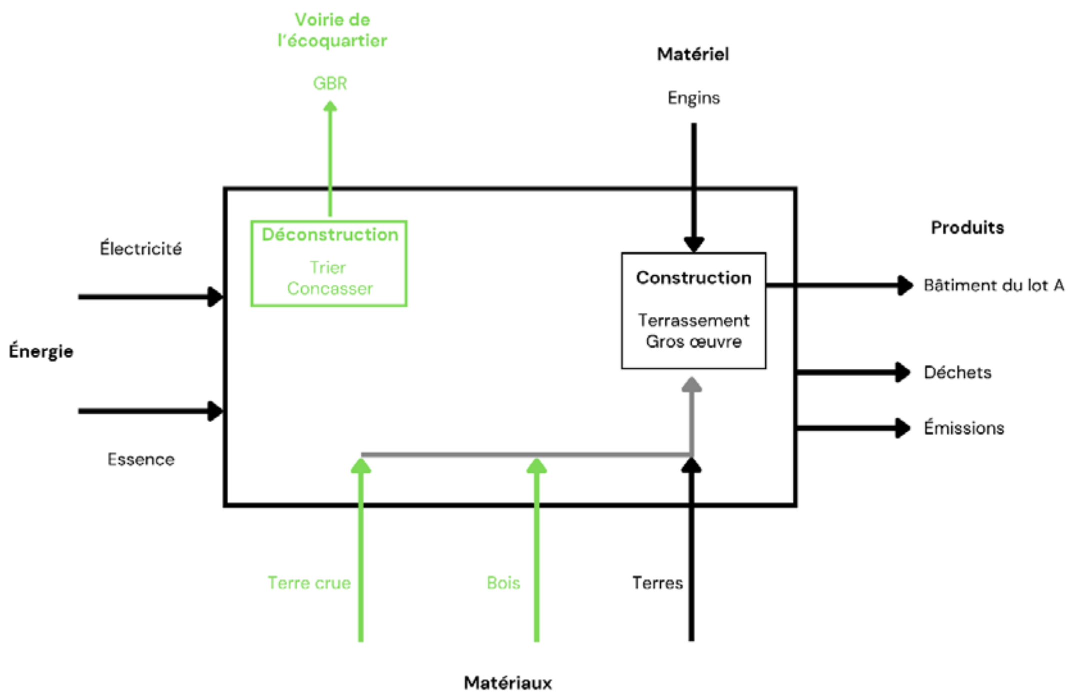
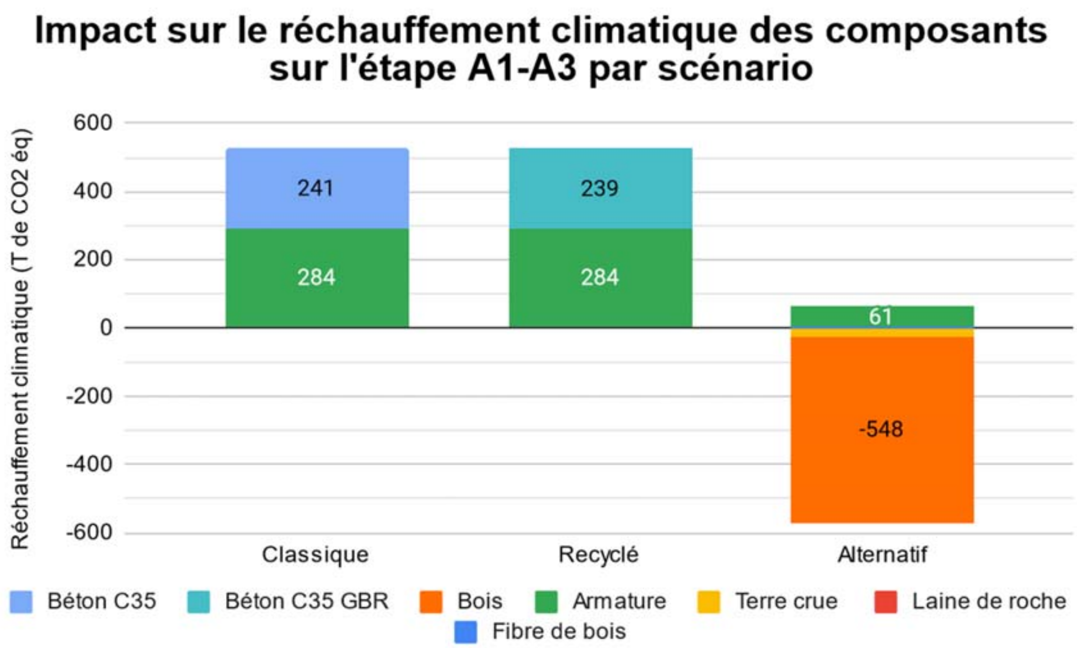
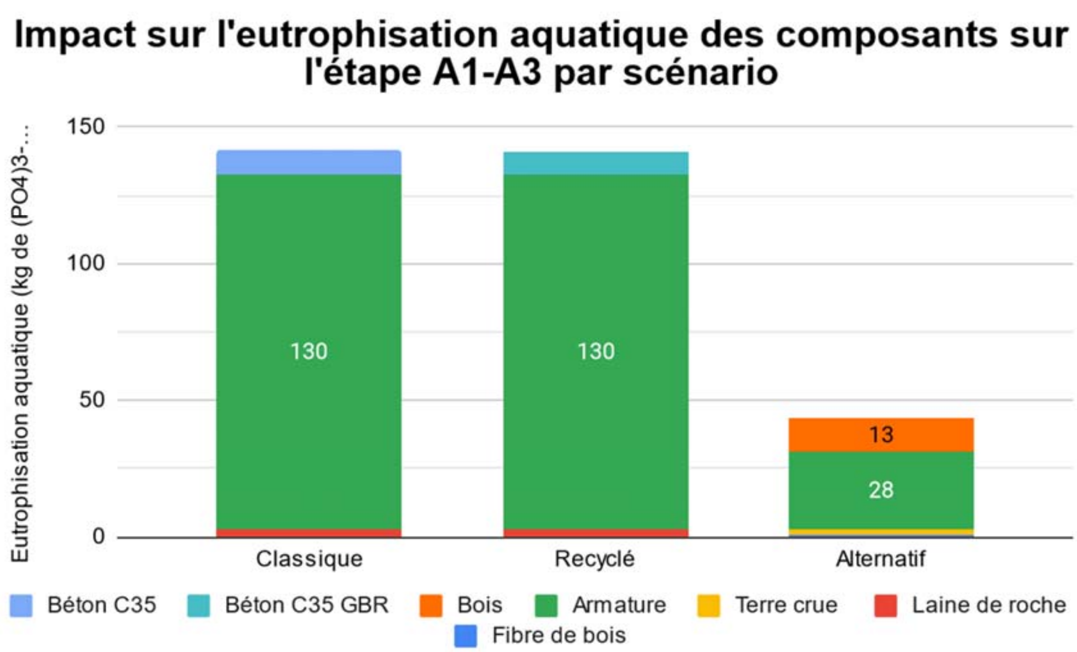


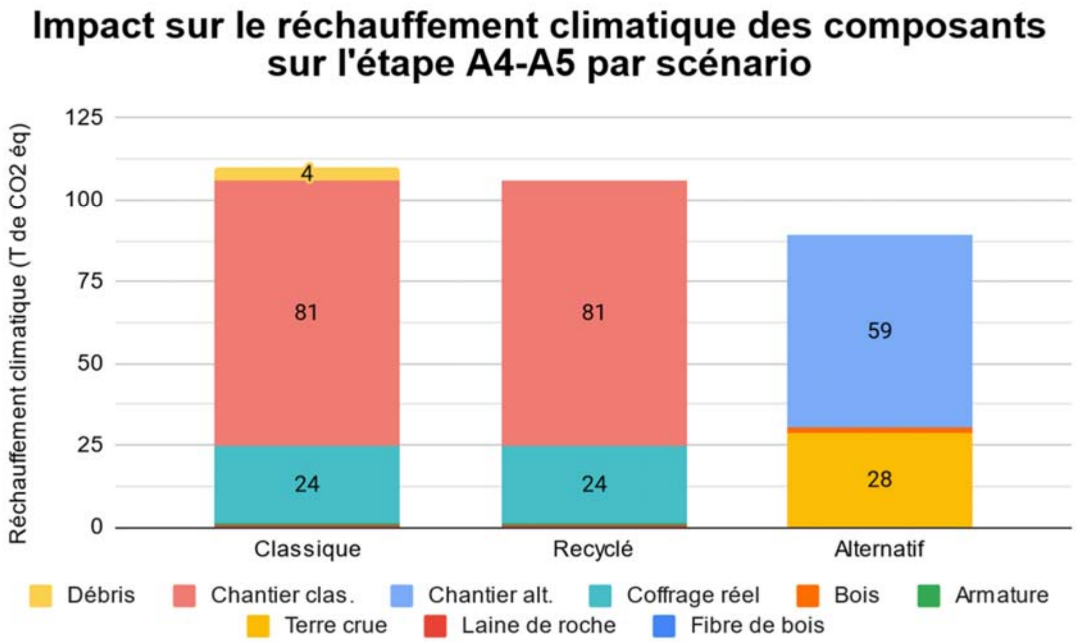
Figure: alternative scenario

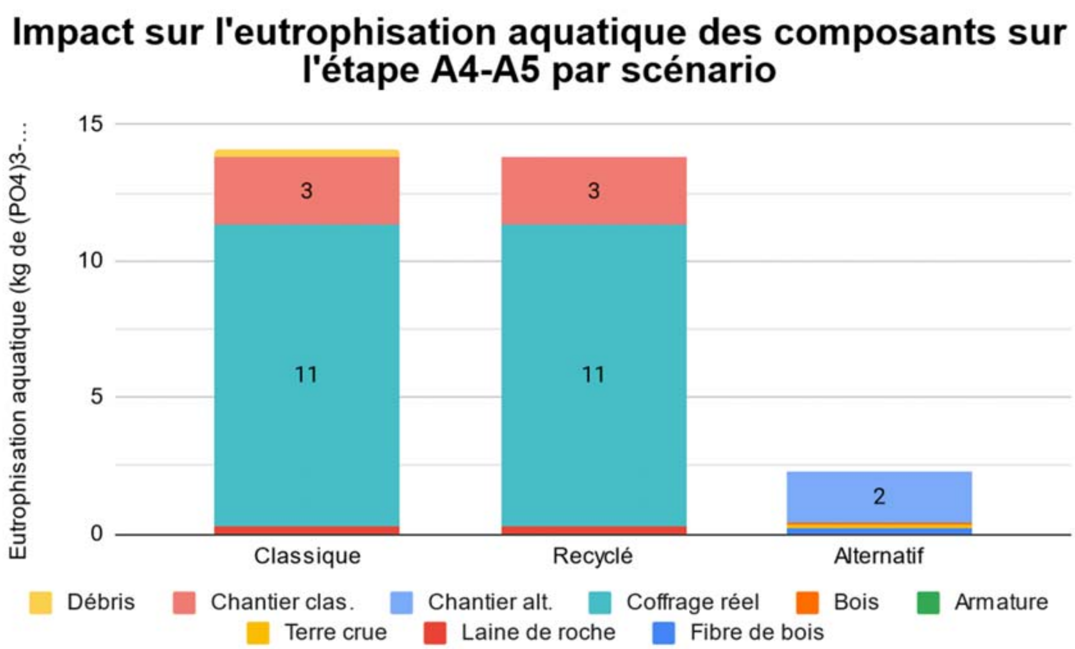
Impact of components on stage A1-A3



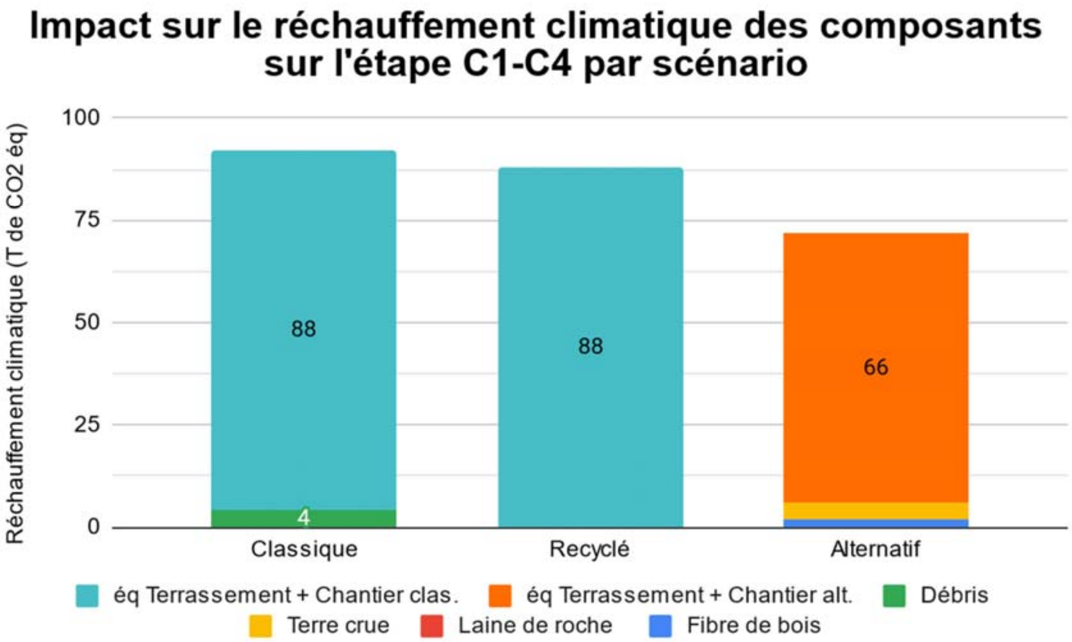


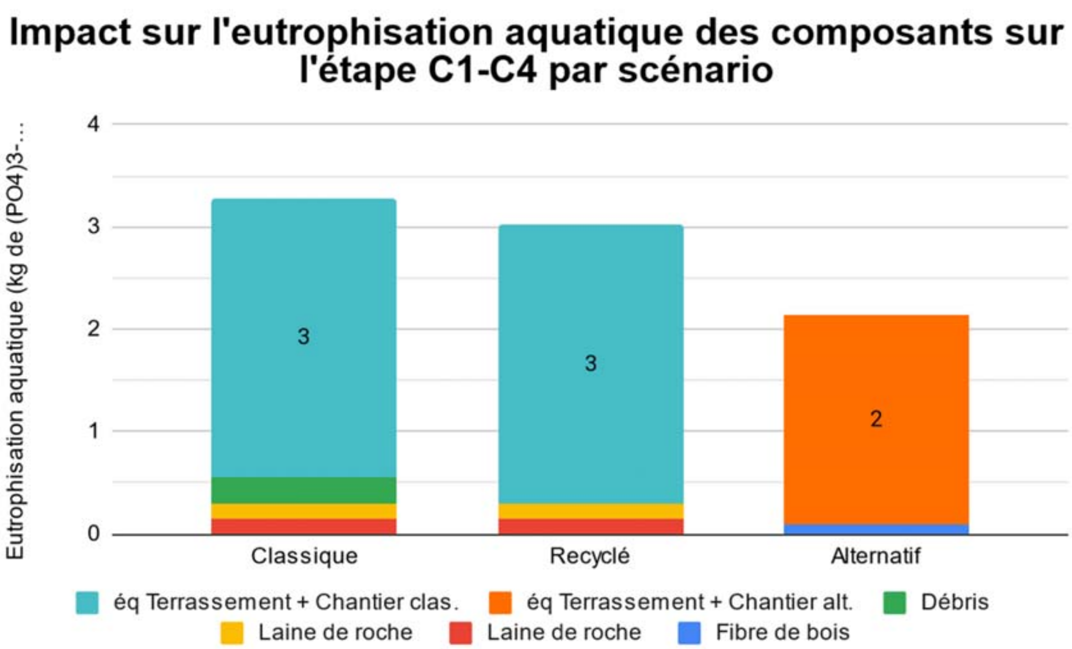
Impact of components on stage A4-A5





Impact of components on stage C1-C3





These results are obtained with an excel calculators that give the results in French, it will be rewrite in English for following ongoing research.

6 Conclusions

This work is an introduction to ongoing research, that should be done on the physical platform chosen by the French pilot. Research will use the simple and robust program done to evaluate quickly environmental indicators. It is following the regulation ISO 14xxx and open database for construction materials, especially with French data.

The specific deconstruction site and waste treatment of the Paris region are used to evaluate transport impact. This will be the case for the physical platform choose for our pilot.

The main conclusions drawn between the two concrete scenarios also apply to the Alternative scenario: materials choice considering production and transports plays a prominent role, and the magnitude of the other two phases is similar. The main difference, when studying variants is the materials choice first and then the transport. For small buildings, wood can be a good alternative to concrete, even using recycled concrete aggregate.

For wood, we can consider the product sheet to have a negative impact on the balance sheet. This assumption imposes a minimum lifespan for the tree before it is cut down, as well as a controlled harvesting of forests, which is mostly the case in France. What this solution achieves on paper therefore depends directly on the territorial policies in place and tends not to be generalizable. The hypothesis therefore needs to be criticized and justified by further knowledge on the subject.

As far as the study is concerned, we have carried out a state-of-the-art life cycle analysis on the LaVallée eco-district building. Improvements and completeness are therefore expected, for example, modelling the construction materials of concrete scenarios using the ratios of Emmanuelle Moesch's study base is strongly recommended.

If raw materials or geomaterials or reuse of such materials is possible, a collaboration with the research done on the methodology to integrate such materials, especially raw materials (earth) in construction in Paris region will be used. This methodology is developed in GERS and MAST laboratories in the frame of Circ-Boost Project.

For further research, in addition to the work presented in this report, we are studying:

- Comprehensive analysis of environmental impact considering life span of buildings (40 years),
- State of the art in the objective to give a comprehensive analysis of the spatial dynamics of these urban areas up to 2050 or more, models of various factors influencing urban environmental impacts and evaluate urban transportation, urban metabolism and all the characteristics of dense areas are proposed.

References

- Abedin Khan, Z., Balunaini, U., & Costa, S. (2024). Environmental feasibility and implications in using recycled construction and demolition waste aggregates in road construction based on leaching and life cycle assessment - A state-of-the-art review. *Cleaner Materials*,*12* , 100239. https://doi.org/10.1016/j.clema.2024.100239

- Aziminezhad, M., & Taherkhani, R. (2023). BIM for deconstruction: A review and bibliometric analysis. *Journal of Building Engineering*,*73* , 106683. https://doi.org/10.1016/j.jobe.2023.106683

- Peuportier, B. (2003). Eco-conception des bâtiments: bâtir en préservant l'environnement. Presses des MINES.

- Cristóbal, J., Foster, G., Caro, D., Yunta, F., Manfredi, S., & Tonini, D. (2024). Management of excavated soil and dredging spoil waste from construction and demolition within the EU: Practices, impacts and perspectives. *Science of The Total Environment*,*944* , 173859. https://doi.org/10.1016/j.scitotenv.2024.173859

- Ding, L., Wang, T., & Chan, P. W. (2023). Forward and reverse logistics for circular economy in construction: A systematic literature review. *Journal of Cleaner Production*,*388* , 135981. https://doi.org/10.1016/j.jclepro.2023.135981

- European Commission. Joint Research Centre. Institute for Environment and Sustainability (2010). *International Reference Life Cycle Data System (ILCD) Handbook :general guide for life cycle assessment : Detailed guidance.* Publications Office. https://data.europa.eu/doi/10.2788/38479

- Fei, Y., Liao, W., Lu, X., & Guan, H. (2024). Knowledge-enhanced graph neural networks for construction material quantity estimation of reinforced concrete buildings. *Computer-Aided Civil and Infrastructure Engineering*,*39* (4), 518-538. https://doi.org/10.1111/mice.13094

- *Guide_re2020_version_janvier_2024.pdf*. (n. d.). Retrieved September 13, 2024, from https://www.ecologie.gouv.fr/sites/default/files/documents/guide_re2020_version_janvier_2024.pdf

- H, D., & S, S. (2022). LCA on Construction and Demolition Waste Management Approaches: A review. *Materials Today: Proceedings*,*65* , 764-770. https://doi.org/10.1016/j.matpr.2022.03.286

- Illankoon, C., & Vithanage, S. C. (2023). Closing the loop in the construction industry: A systematic literature review on the development of circular economy. *Journal of Building Engineering,76* , 107362. https://doi.org/10.1016/j.jobe.2023.107362

- Lachat, A., Mantalovas, K., Desbois, T., yazoghli, O., Colas, A.-S., Mino, G., & Feraille, A. (2021). From Buildings' End of Life to Aggregate Recycling under a Circular Economic Perspective: A Comparative Life Cycle Assessment Case Study. *Sustainability*, 27. https://doi.org/10.3390/su13179625

- Mielniczek, A., Roux, C., & Jacquinod, F. (2023, September 6). *Benchmark of ecodesign LCA tools at neighborhood scale*. LCM 2023 , the 11th International Conference on Life Cycle Management. https://hal.science/hal-04248215

- Moncaster, A. M., Rasmussen, F. N., Malmqvist, T., Houlihan Wiberg, A., & Birgisdottir, H. (2019). Widening understanding of low embodied impact buildings: Results and recommendations from 80 multi-national quantitative and qualitative case studies. *Journal of Cleaner Production,235* , 378-393. Scopus. https://doi.org/10.1016/j.jclepro.2019.06.233

- Nußholz, J., Çetin, S., Eberhardt, L., De Wolf, C., & Bocken, N. (2023). From circular strategies to actions: 65 European circular building cases and their decarbonisation potential. *Resources, Conservation & Recycling Advances,17* , 200130. https://doi.org/10.1016/j.rcradv.2023.200130

- Nußholz, J. L. K., Rasmussen, F. N., Whalen, K., & Plepys, A. (2020). Material reuse in buildings: Implications of a circular business model for sustainable value creation. *Journal of Cleaner Production,245* , 118546. https://doi.org/10.1016/j.jclepro.2019.118546

- Ossio, F., Salinas, C., & Hernández, H. (2023). Circular economy in the built environment: A systematic literature review and definition of the circular construction concept. *Journal of Cleaner Production,414* , 137738. https://doi.org/10.1016/j.jclepro.2023.137738

- Peuportier, B., & Roux, C. (2016). Eco-design of urban sttlements using LCA. In *LCA [avniR] Conf. 2013, Proc. 3rd Int. Conf. Life Cycle Approaches* (p. 6).

- Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production,143* , 710-718. Scopus. https://doi.org/10.1016/j.jclepro.2016.12.055

- Pristerà, G., Tonini, D., Lamperti Tornaghi, M., Caro, D., & Sala, S. (2024). Taxonomy of design for deconstruction options to enable circular economy in buildings. *Resources, Environment and Sustainability,15* , 100153. https://doi.org/10.1016/j.resenv.2024.100153

- Rasmussen, F., Birkved, M., & Birgisdóttir, H. (2019). Upcycling and Design for Disassembly - LCA of buildings employing circular design strategies. *IOP Conference Series: Earth and Environmental Science,225* , 012040. https://doi.org/10.1088/1755-1315/225/1/012040

- Rasmussen, F. N., Malmqvist, T., Moncaster, A., Wiberg, A. H., & Birgisdóttir, H. (2018). Analysing methodological choices in calculations of embodied energy and GHG emissions from buildings. *Energy and Buildings,158* , 1487-1498. Scopus. https://doi.org/10.1016/j.enbuild.2017.11.013

- Rayegan, S., Wang, L. (Leon), Zmeureanu, R., Katal, A., Mortezazadeh, M., Moore, T., Ge, H., Lacasse, M., & Shi, Y. (2024). Achieving carbon neutrality at single and multi-building complex levels - A review. *Energy and Buildings,314* , 114263. https://doi.org/10.1016/j.enbuild.2024.114263

- Rodriguez-Morales, J., Burciaga-Diaz, O., Gomez-Zamorano, L. Y., & Escalante-Garcia, J. I. (2024). Transforming construction and demolition waste concrete as a precursor in sustainable cementitious materials: An innovative recycling approach. *Resources, Conservation and Recycling,204* , 107474. https://doi.org/10.1016/j.resconrec.2024.107474

- Roux, C., Kotelnikova, N., Schalbart, P., & Peuportier, B. (2017). *Comparison of attributional and consequential LCA applied to urban projects.* https://doi.org/10.13140/RG.2.2.20973.28645

- Sivashanmugam, S., Rodriguez, S., Pour Rahimian, F., Elghaish, F., & Dawood, N. (2023). Enhancing information standards for automated construction waste quantification and classification. *Automation in Construction,152* , 104898. https://doi.org/10.1016/j.autcon.2023.104898

- *Veille - Artificialization and material flows in the construction industry: the importance of a circular approach*. (n.d.). Retrieved August 21, 2024, from https://chaire-ecmu.univ-gustave-eiffel.fr/ressources/veille/artificialisation-et-flux-de-matieres-du-btp-limportance-dune-approche-circulaire

- Wu, L., Sun, Z., & Cao, Y. (2024). Modification of recycled aggregate and conservation and application of recycled aggregate concrete: A review. *Construction and Building Materials,431* , 136567. https://doi.org/10.1016/j.conbuildmat.2024.136567

- **Xue, K., Uzzal Hossain, M., Liu, M., Ma, M., Zhang, Y., Hu, M., Chen, X., & Cao, G. (2021). Bim integrated lca for promoting circular economy towards sustainable construction: An analytical review. *Sustainability (Switzerland),13* (3), 1-21. Scopus. https://doi.org/10.3390/su13031310**

- **ISO 14040:2006. Environmental management - Life cycle assessment - Principles and framework. International Organization for Standardization, 2006.**
- **Peuportier, B. (2023). *Life cycle assessment in urban projects*. Eyrolles.**

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Co-funded by
the European Union