FutuREuse

Evaluating the technical performance of reclaimed building materials

Belgian Building Research Institute and Centre Scientifique et Technique du Bâtiment for

Interreg
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REUSE IN THE CIRCULAR ECONOMY

In the European Union and around the world, construction materials have a massive impact on climate change, ecosystems collapsing and natural resource overconsumption. As a waste prevention strategy, reuse is a great solution to overproduction and natural resource depletion.

Despite its waste prevention potential, the salvage and reclamation trade is largely overlooked, especially in the context of formal construction projects. Better consideration for this approach in tools widely used by the construction industry would be interesting leverage to foster, support and further develop the reclamation sector.

THE FCRBE PROJECT

FCRBE stands for Facilitating the circulation of reclaimed building elements and aims to increase by 50%, the amount of reclaimed building elements being circulated on its territory, by 2032. The project involves 7 partners:
Rotor, lead partner (BE), **Bellastock** (FR), **Brussels Environment** (BE), **The university of Brighton** (UK), **Salvo** (UK), **Construction Confederation** (BE), **Belgian Building research Institute** (BE) and the **Scientific and Technical Center for Building** (FR)
For more information on FCRBE: *http://www.nweurope.eu/fcrbe*

FUTUREUSE: 7 SHORT INTRODUCTIONS TO THE WORLD OF REUSE

This is one of a series of seven booklets that have been produced to serve as a taste of what the FCRBE project aims to achieve. The subjects span the broad spectrum of reuse, covering considerations before, during and after with useful information to guide and inspire working with reclaimed materials. The booklets also highlight environmental benefits, clarify grey areas and frequently asked questions regarding best practices, whilst sparking curiosity for a future where use is reuse.

AUTHORS’ NOTE

The use of the term « building materials » in this document refers to Products, Materials or Equipment found in a building.

CONTENT

1.

Introduction: Technical performance of new and reclaimed materials

Generally speaking, when a **new material** is used during construction, it is accompanied by a technical datasheet stating its performance specifications. These specifications make it possible for the buyer to be assured that the properties of the material correspond with the requirements of the building specifications and also with current regulations. The technical datasheet also states the way in which the material's performance is measured, whether in accordance with a standard, a technical requirement or a technical approval or accreditation. Also, if the material is covered by a harmonised standard or technical assessment, the manufacturer is obliged to draw up a performance statement and apply CE markings to its materials. These markings attest to the reliability of the information stated about the material's performance. Voluntary certifications are also possible.

With **reclaimed materials**, the situation is usually very different. It is much more unusual for these materials to have technical documentation and, even if they do, this documentation is practically never drawn up in accordance with the procedures applied to new materials. In addition, if some performances had been stated, they may no longer be valid. This situation can restrict the reuse potential for materials.

This booklet will try to answer the following question: How can we be sure of the suitability for use of a reclaimed material? Various methods and approaches will be explained. Other questions on the same topic will also be broached. What are the differences and similarities between new and reclaimed materials from the point of view of justifying their fitness for use? Who are the actors involved and what might the distribution of the responsibilities be between them in terms of the way the various parties are configured?

1.1 What is similar?

1.1.1 Fitness for use: Technical requirements in function of application

To be able to be used again, a reclaimed material must demonstrate that it is 'of a certain quality', just like a new material. This quality includes the notion of *fitness for use*. In other words, any material must be suitable for its purpose (its function), and consequently it must present suitable characteristics for meeting the needs of the intended use. Again, just like new materials, it is the intended use that sets the requirements that need to be met. This intended use must be identical to the material's original use, or different. One of the strategies that enables the effective reclamation of building components is to use these components in applications that are less and less demanding, such as reusing structural materials for non-structural purposes. This is called 'cascade use'.

1.2 What is different?

1.2.1 Factory production versus second life: different sources of information

Although reclaimed materials need to demonstrate a certain degree of suitability for use, like new materials it is often not possible to identify and evaluate their level of performance in the same way.

New materials are mass-produced in a controlled environment. The performance consistency of these materials is verified by checks and evaluations, some of which are conducted by the manufacturer and some by accredited bodies. As a result, there is little doubt as to the stated performance and the homogeneity of the production process.

Reclaimed materials have a history

Reclaimed materials do not come out of an environment that is as controlled as an industrial production line. During its first working life, for instance, the material may be affected by a range of factors, causing a modification to its original performance. For example, tiles may become more porous over the years.

However, in some cases, the level of performance can also increase. For instance, VOC emissions from construction materials tend to decrease over time. This means that **current performance** needs to be considered as **uncertain** when it comes to evaluating these materials. This booklet features several methods that make it possible to reduce this uncertainty and to evaluate the current performance of reclaimed materials.

One of the avenues of work consists of gathering information derived from knowledge of the origin and history of materials. Knowing that materials have already spent a certain amount of time in a building or other application and continue to fulfil the function for which they were initially implemented is a **source of quality information**. As a result, methods of evaluation based on this knowledge can be developed (see 2.4).

Reclaimed materials come from 'deposits' of reclaimed materials

Once dismantled and sorted, cleaned and repaired, etc. where applicable, reclaimed materials are generally presented in the form of material batches displaying more variations than new materials that are fresh out of the factory. This heterogeneity may result from a range of factors:

- the original materials may be variable in composition due to the production techniques used (for example old bricks fired on-site in several batches),
- the materials may have aged differently, depending on where they were used in the original building and the stresses and strains they have been subject to (see paragraph below),
- the materials may come from different buildings (for example batches or bricks or cobbles of a similar type collected by a specialised supplier).

In that case, you need to take these possible differences in batches into account when assessing performance. Some ways of working can help boost confidence in the homogeneity of batches. One way may be to make sure that the batches come from the same 'deposits' – i.e., from the same groups of materials or components in a particular area, with shared characteristics and history.

Dismantled materials are prepared to be reused

Once dismantled, used materials usually go through a series of stages that prepare them for reclamation: cleaning, repair, reconditioning, storage, resizing, etc. These processes may be handled by professional operators specialized in the reclamation of this or that material. It may also be that building companies handle these processes as part of their work and especially if the materials are to be reclaimed on the same site. In all cases, the various stages are usually an opportunity to conduct a careful sort through the materials. This process may also help ensure that the batches dealt with in this way are suitable for (re)use.

1.2.2 Should we be more tolerant?

Because reclaimed materials are intended to be incorporated sustainably in construction works and because the way they perform has an effect on the way their new purpose also performs, like new materials, they should be considered as construction materials. This means that they need to meet a few *essential* requirements, such as the demands relating to the regulations that apply to building works (for example, the regulations regarding fire safety), as well as regulations on the health and safety of users. In addition to these essential requirements, reclaimed materials must also meet other, *additional*, demands that are necessary for them to be suited to the purposes they are intended for. According to their intended use and the main contractor, some requirements may be less strict than for a new material. This means that the main contractor may decide to accept minor defects that would have caused new materials to be rejected, such as slight wear marks on parquet flooring, or traces of mortar on bricks.

This means that reclaimed materials must perform in a way that meets the same (essential) requirements as new materials. However, the ways of measuring and stating this performance are bound to differ[1].

Indeed, the harmonised procedures for tests and for declaring performance, as provided for in the standards, do not always appear to be suitable and geared to the specific requirements of reclamation. They are designed mainly for mass production in a controlled environment and do not take account, in particular, of the potential lack of homogeneity of reclaimed materials or the lack of certain information. From a practical point of view, they often cannot be implemented due to the smaller quantities of reclaimed materials and their cost – and they do not take account of some of the advantages of reuse. It is for this reason that alternative methods are put forward in the next section.

1 See FCRBE toolkit Technical Sheets for Reclaim Materials

2.

Evaluation of technical performance: description of approach

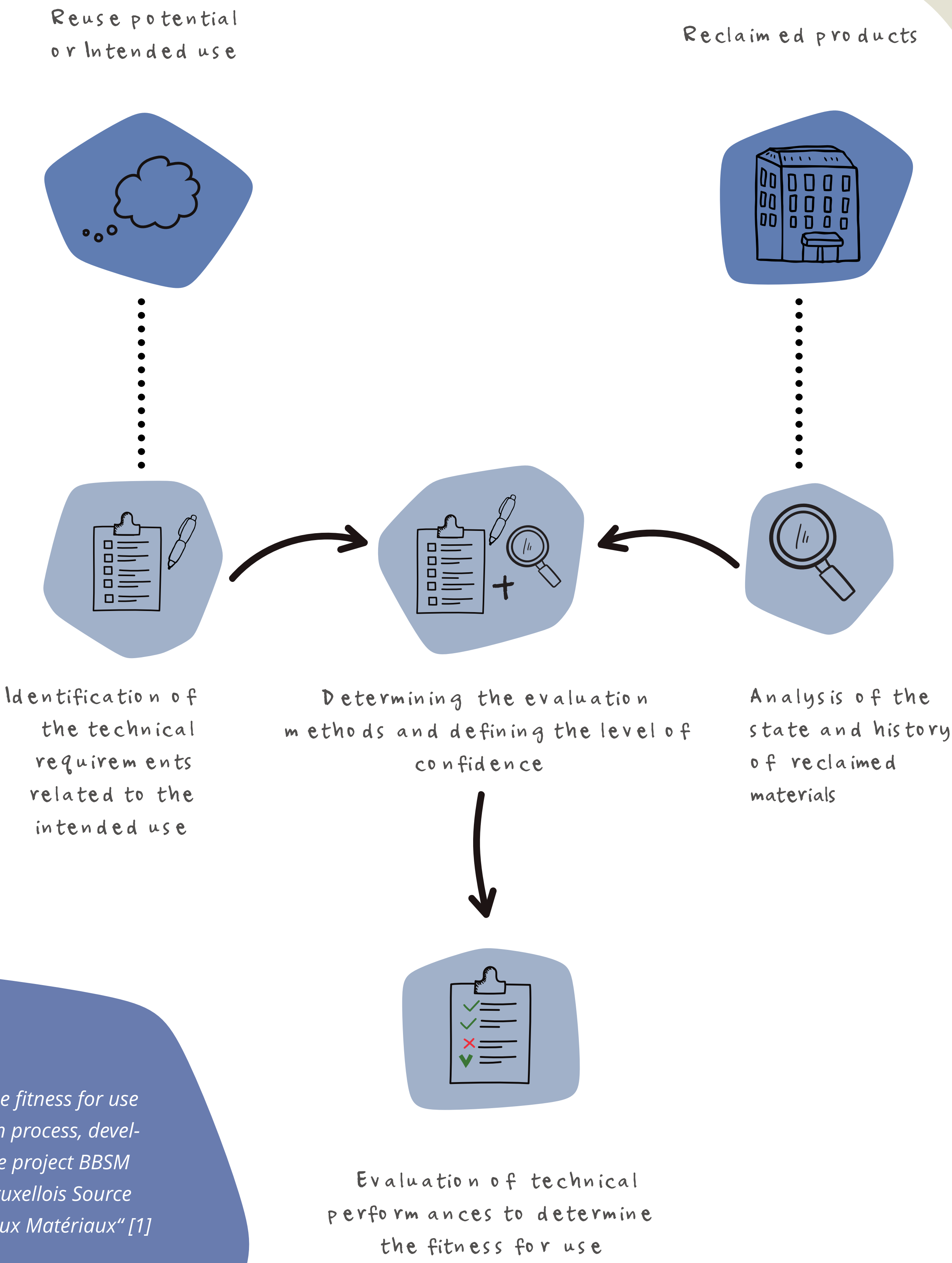
As discussed before, in case of reuse, we are often challenged by the absence of the original documentation that ensures the suitability of a reclaimed material for use. In order to justify the fitness for use, we resort to evaluating different technical performances of the material. This process varies significantly depending on the type of material or project as well as the time and place of this evaluation. It can be done at different stages of the reclamation process depending on the actors involved and the technical performances to declare. The general steps presented below may be adapted to each project; their order may be reversed, or some steps may be omitted, depending on the stage of the project or even the actor concerned.

These 4 general steps can be presented as follows:

1. *Identifying the technical requirements to be assessed in light of the intended use and the reuse potential of the reclaimed material*
2. ***Gathering relevant information on the material***
3. ***Defining the level of confidence needed and determining the evaluation methods of the required technical performances of the material***
4. *Evaluating the technical performances of the reclaimed material*

To identify the technical performances to be assessed (step 1), the intended use should be known. However, the intended use and function of the material may still be unknown at the time of this evaluation. In this case, it is necessary to evaluate as much of the below-technical performance that concerns the most potential-intended use of the reclaimed material as possible. It is also possible that the actor carrying out the evaluation knows exactly what the intended use of the reclaimed material is, thus focusing on certain performances and dismissing others, for example: acoustic or thermal properties are not always required.

Step 2 can either take place before deconstruction in case the material is still 'in place' in its original project or after deconstruction in case a reclaimed material is present on the market without a known history. In this case, it will not be possible to collect information on the previous application, but the procedure can still be applied.



Steps of the fitness for use verification process, developed in the project BBSM „Le Bati Bruxellois Source de nouveaux Matériaux" [1]

2.1 Identification of technical requirements

When the intended use of a reclaimed material is identified or estimated, technical performances that are associated with this use are to be evaluated. Considering this intended use, these technical requirements can be either *Essential* Requirements, whose validation is obligatory, or *Complementary* Requirements, whose validation is perceived necessary depending on the material and project conditions.

We can find these technical requirements in four main levels depending on their importance:

1. ESSENTIAL REQUIREMENTS	
1.1 Essential regulatory requirements	According to the regulations that are applicable: • Thermal performance • Indoor air quality • Hazardous substances • Acoustic performance • Environmental performance • Fire resistance and fire reaction • Seismic performance • Mechanical resistance and stability
1.2 Essential requirements related to health and security of occupants	Necessary for the materials to be fit for use taking into consideration the potential health and security risks. Related to specific material standards, for example: anti-skidding performance of floor finishes.
2. COMPLEMENTARY REQUIREMENTS	
2.1 Complementary requirements related to fitness for use	Related to project specific performances, for example: water permeability, mechanical properties, chemical resistance, humidity conditions...
2.2 Complementary requirements particular to project specifications	Related to design or aesthetics material specification, for example: colour, dimensions, weight, texture.

2.2 Gathering information on the reclaimed material

It is useful to collect as much information as possible about the material, its domain of use and its function in its first lifetime as well as information on the existing building. As when it comes to assessing the suitability of the material for use, this information can help choose the representative samples and create homogenous lots of materials but can also be used to make hypotheses or assumptions about the current performance of materials and allow for the evaluation of its performances using different methods (see 2.4).

It is preferable to start gathering information on the material when it is still 'in place' right before extracting it from the project at the end of its first lifetime. This will provide useful information about the factors that may have affected its performances, like the exposure to weather conditions (South-West façade versus other façades), mechanical loads (load bearing wall versus architectural wall), location in project (in a common area in a residential building versus in an individual apartment). However, the information gathered when the material is still in place can be affected by the process of extraction, transportation and refurbishment that the reclaimed material will undergo, hence special attention must be taken that the characteristics initially determined remain valid throughout these processes.

It is also very common to encounter a different case where reclaimed materials have already been extracted and put into the reclamation market without having prior information about their history or their first lifetime. If this is the case, and as a first step, we resort to collecting the obtainable information from the ones listed below. Some of this information may have been already obtained during the reclamation audit, while others will require a supplementary audit.

2.2.1 Information related to building

- Construction date of the building and the regulations in place at that date
- Past interventions and renovation processes that might have affected the material
- The location and the type of the building, which relate to design against seismic, wind and snow loads as well as applicable fire regulations

2.2.2 Information related to material

- Technical information found in construction documents related to the nature of the material and its installation in the building as well as any calculation notes, execution plans and technical notes available: Material category, manufacturer's name, material datasheet, method statement, geometric characteristics, weight...
- Observed deterioration in the material condition (cracks, corrosion...), their probable cause, the percentage of affected parts...
- Material quantity available for reclamation
- Possibility of extraction of material and proposed deconstruction method

2.2.3 Information related to the first lifetime of the material in the building

- Date of installation of material in the building
- The actual domain of use of material in the building (example: ceramic tiles used as flooring in toilets...)
- The material's installation technique: adhesives, welding, screws...
- Exposure to external weather conditions (close to sea, industrial polluted zone...) or internal conditions that might affect its properties like humidity
- Exposure to other conditions like chemical attack, salts, carbonation...

2.3 Determination of evaluation methods and the level of confidence needed

Determining the level of confidence when evaluating technical performances of a reclaimed material is not yet subject to defined rules. It can be influenced by the importance of the technical performance in question; an *Essential* performance would require a high level of confidence. Moreover, it can also depend on many other factors in the reclamation process: material status, project condition, project actors, intended function, intended use domain, country regulations, technical controller, insurance requirement as well as the extent of availability of information from visual examination and documentation. Different methods of evaluation of technical performances exist and offer reliable results. Some methods deliver more precise results than others but are not necessarily feasible in all reclamation processes. It will thus require a choice between the applicable evaluation methods for each reclamation process separately. A strategy could be to combine different types of methods or to account for safety factors when faced with uncertainty, for example: the over-dimensioning of structural elements.

Due to a failure in water-tightness, these bricks have been in contact with water more than the rest of the deposit. Their condition is likely to have deteriorated, particularly during freeze/thaw cycles. On deconstruction, the gathering of this information will enable these items to be removed from the rest of the batch so that the batch can be made more homogeneous.

2.4 Evaluation methods

The evaluation of the previously mentioned technical performances is essential for their validation. The validation method will depend on each material and its condition, as well as on the technical performance in question. We present three main types of evaluation methods and two types of alternative evaluation methods. These different evaluation methods can be complementary and form part of a procedure, which can extend from the dismantling process until after the installation of the reclaimed material in a new project.

2.4.1 Principal evaluation methods

a. ***Direct evaluation***

If the performance can be visually checked or measured by non-destructive technical means, it can be directly validated when the material is still in situ or when it is extracted. This includes direct visual verification of material colours, dimensions, and deterioration state (measurement of visible cracks). It may also consist of tests: for example, on-site testing method for natural stone by determination of sound speed propagation using the necessary equipment. On-site tests and verifications developed in the context of renovation can also sometimes be adapted to the case of reuse.

b. ***Indirect evaluation from existing documentation and historical information***

Some performances can be deduced from information relating to initial or historical performance of the material. This verification uses existing documents related to the material and the history of the project: technical datasheets, test reports, material technical and environmental certifications, national regulations in force during installation, and standards that control the production and installation of the material. Any other document that provides information about the origin of the material and its components can serve as an essential source of information. As explained before, it should be kept in mind that even if the declared initial performance is known, it may have been modified.

For example, **the reaction to fire of panels of mineral wool** can be evaluated indirectly. The material standards of mineral wool materials indicate that the reaction to fire performance of these materials does not vary over time, under certain conditions. This means that, most of the time, mineral wool can again be declared incombustible, with even more certainty if a technical datasheet is still available, which attests to its original performance. It will simply be a question of verifying that the material is indeed mineral wool.

For example, the dimensions of panels of mineral wool can be measured directly, on-site or off-site. Other types of performance, such as mass density, squareness or flatness can be measured in the same way, with the evaluation of these performances only requiring limited equipment.

Another requirement that applies to mineral wool panels relates to the ***health of users****. The CLP directive classifies mineral wool as a type-2 carcinogen (suspected of causing cancer in humans), except if it fulfils certain conditions. However, in practice, it can be difficult to verify these conditions for materials to be reused, with these conditions relating to the composition of the panels. Nonetheless, following this directive, it appears that since the 2000s, all mineral wool has been manufactured in such a way as to be non-biopersistent (therefore fulfilling the conditions of the directive). Knowing when the panels were manufactured could therefore make it possible to state whether or not this requirement has been met* [2].

Indirect evaluation may also consist of making assumptions about performance based on knowledge of the previous application. The knowledge of the location of the material in the original project, its exposure to wearing factors, knowledge of construction rules in force at the time of installation, as well as the history of a refurbishment of the material can facilitate the material evaluation process.

Let's take the example of terracotta bricks that have been in a southwest-facing wall for the past 50 years. As facing the southwest is generally the most wearing orientation in terms of damage caused by frost, the bricks are likely to be relatively resistant to frost-thaw cycles if they currently display no damage. This means they could potentially be suitable for a similar application. The composition of the wall can also give us some additional information. If during renovation works dating back ten or so years the walls were given thermal insulation, we can be more certain about the ability of the bricks to withstand frost in a similar application, i.e., for the facing of an insulated wall. In fact, bricks in an insulated wall will undergo greater differences in temperature than those in a non-insulated wall – which means they will certainly have been affected more by freeze/thaw cycle.

When it comes to regulatory requirements, the actor handling the evaluation process can start with any available documentation related to the reclaimed material while consulting the regulations at the time of the installation of the material in its first lifetime. This information can help to identify the regulatory performances the material must have satisfied at that time. After consulting the updates these regulations have undergone until the present time (the time of the evaluation), the evaluator will be able to predict whether the reclaimed material still conforms to the countries' regulations. To confirm this assumption, it will be necessary to verify in some way that the initial performance has not deteriorated. Further evaluation of the condition of the material at the time of its reclamation and the history of a refurbishment of the material during its first lifetime is necessary. After that, the reclaimed material can undergo a process of re-testing (see other evaluation methods) of some technical properties if still needed: outdated test reports, obvious deterioration in material conditions, change in regulatory requirements, refurbishment works, for example, painting the material.

c. *Laboratory testing method*

Verification using laboratory-controlled tests on a sample of the material in question can take place during the deconstruction process or during the reconditioning process. As expected, some classical material evaluation methods, like calculation methods or certain laboratory tests, do not apply in case of a reclaimed material. The following points will require special attention:

- *Destructive tests*

  Laboratory tests can be destructive. It will therefore be necessary to ensure that we can accept damage to some of the reclaimed elements. Otherwise, an alternative will have to be found.

- *Laboratory testing methods customised for reclaimed materials*

  Standards for new materials often describe test methods to assess their technical performance. However, some laboratory tests that suit new materials are not quite adapted to be applied to reclaimed materials that might possess different characteristics.

For example, the test methods used for the determination of slip resistance of a cobblestone surface require a flat surface for the tested sample. Thus, if the reclaimed material has a curved surface, another test method is to be developed to test its slip resistance.

Reclaimed stones

- *Statistical approach for testing reclaimed materials*

  Moreover, the application of a different statistical approach is most of the time necessary when choosing the testing sample, since the test protocols are based on a standardised production of new materials which have a controlled production. It is important to choose to test a large number of samples if possible: the smaller the number of samples, the less the level of confidence; example: the results of testing 10 out of 1000 reclaimed bricks will be better than testing 1 out of 1000 reclaimed bricks, although they won't likely reflect true results. The choice of the number of samples will depend on the type of material, the degree of importance of the requirement, but also of the possible other evaluation methods combined, and whether a homogeneity check has been carried out.

In this example, it was decided to conduct laboratory tests to evaluate porousness and resistance to compression and frost-thaw cycles on bricks in different deposits at the same site. The tests were as described in national standards and identical to those conducted on new bricks. The bricks themselves were still in place, which enabled a certain amount of information to be obtained and to adopt an approach suited to various deposits in order to limit the cost of testing. The evaluation method using tests was combined with direct and indirect methods of evaluation.

In addition to the quantity of bricks, factors making it possible to provide more or less confidence in the various deposits of bricks, such as their previous application (bricks in the external walls of heated rooms, internal walls or garden walls), the type of brick (for example hand-moulded bricks versus industrial bricks), and their general condition were taken into consideration to determine the number of samples needed per deposit and per type of test.

For instance, for the compression test, the recommendation was to test proportionally more samples of bricks from garden walls than bricks from walls of a greater height. In the same way, for the test into resistance to frost-thaw cycles, more samples were tested for the internal walls of houses, as these bricks were likely to be less able to withstand frost.

- *Strategies to reduce the number of tests*

  If reclaimed materials from the same origin have been separated into different groups based on their degradation, the testing can start with the group that appears to have experienced the most degradation, a number of elements are chosen to be tested given that the results will represent the whole group due to its homogeneity. Furthermore, if this group successfully passes the testing and verification of its fitness for use, there remains no need to test the other groups that are in a better condition.

Photo credit: De Ideale Woning

Samples of dismantled bricks for testing

Furthermore, another strategy can be to choose to test the materials that have in theory deteriorated the most due to their location in the project; for example: testing facade cladding reclaimed from the façade subject to the harshest weather conditions to assess the cladding reclaimed from other facades. This proves the importance of maintaining the traceability of reclaimed materials after deconstruction.

- *Correlated performance tests*

  Tests of other performances could also be carried out, and the results correlated in order to obtain an approximation of the performance. For example, although a calculation method has not yet been developed, a connection between absorption/ desorption of water and brick resistance to freeze/thaw cycles has been observed [3]. The absorption test is simpler to perform, and therefore in practice more feasible than expensive freeze/thaw cycle resistance tests. This type of evaluation
  seems promising for the field of reuse.

2.4.2 Alternative evaluation methods

a. Chain control

When applying what we call 'chain control' to reclaimed batches, components whose performance is unlikely to meet the required performance level can be eliminated by a practitioner who has the knowledge and experience to detect defective materials. The emphasis is no longer placed on an accurate assessment of material performance, but on reliable actors' skills to carry out these procedures due to their prior experience in reclamation processes. This is therefore a sorting process, which not only removes the damaged elements, but also makes it possible to assess whether these elements meet a certain requirement, without always being able to give a precise value.

For example, some providers specialising in the reuse of bricks sort the bricks based on the sound they make when they are knocked together. The sound they make provides an indication as to the presence of cracks or not – and hence their liability to frost damage.

b. Assessment after installation

Performance can be evaluated once the material is implemented. The process for this type of evaluation, which is more risky than others, was to start again if the material did not meet requirements. This method is suited to verifying additional requirements or in combination with other methods of evaluation. For example, this method may be particularly well suited to the reuse of technical installations, as it is linked to the monitoring of performance. In the same way, the homogeneity of the colour of carpet squares can be verified once they are installed.

2.4.3 The importance of the homogeneity

In addition to these different evaluations, a control of the homogeneity of the materials is crucial, especially in case the reclaimed materials come in batches or as a group of elements, for example: bricks, tiles... If it is demonstrated by one or more of the methods described above that a reclaimed element meets the requirements, it must be verified that the entire batch is in the same or similar condition as this element. This can be checked via 'chain control', but it can also be done by non-professionals via a visual inspection (see point 2.2 which lists criteria to be paid attention to), for example: assembling a collection of reclaimed bricks that includes bricks with hair cracks, discoloured bricks, ordinary bricks into 3 homogenous groups. If possible, the elements can also be separated according to their origin: same initial application and same initial installation.

To enable materials to be separated into different batches and their initial implementation, ideally there needs to be a certain degree of tracing the origin of the components so that the historical information gathered before and after dismantling can be preserved. Specific clues that may differ according to the types of materials can also be gathered: for example, bricks protected from the rain by a ledge do not constitute a very representative example of the remainder of the batch and will not be selected as a sample during tests. Selective dismantling depending on the deposits identified and their visual characteristics may also make it possible to save time subsequently.

Photo credit: BBRI

Given the different colours of the bricks present, as well as the differences in mortar, it seems wise to divide up these bricks into separate batches from the time of dismantling onwards.

3.

Discussion: Stakeholders and Responsibilities

3.1 Who does what?

In the classical scenario, where a new material is installed in a project, certain actors, like the project owner, the architect, the material manufacturer, the contractor, and the technical controller, are commonly involved in material-related processes (prescription, procurement, installation and control). These actors perform their well-defined roles in the project while abiding by existing national standards and regulations.

The developer/owner and the architect are responsible for making design choices that make sure the materials integrated in their project meet technical, regulatory and aesthetic requirements. They specify the characteristics and specifications of the materials to be installed in the project.

The manufacturer provides technical documentation related to the manufactured material such as the material's declaration of performance, which is required for each construction material covered by a European harmonised standard. The manufacturer can choose to declare other material characteristics through voluntary performance declarations and labels. All this information is communicated through the material's technical documentation: datasheets, catalogues, specification extracts...

The contractor procures a material that complies with the specifications defined by the architect and installs it in the project.

The technical controller is a third-party actor commonly appointed by the project owner to validate the compliance of the materials installed by the contractor throughout the construction period.

A reclaimed material, like a new material, may undergo multiple performance assessments and tests before it becomes ready for reuse. However, these steps are not visible to the project actors (project owner, architect, contractor) when they prescribe a new material. While in the case of reuse, these actors can find themselves involved in a technical process they are unfamiliar to. Therefore, new actors emerge to take part in the reclamation process, while new roles for already existing actors are also introduced. The roles of these actors in the reclamation process, presented below, can vary depending on the reclamation scenario in place.

- **Project Owner, architect, and engineer**: Explore the possibilities of integrating reclaimed materials in their project while ensuring that the reclaimed materials meet the project's technical, regulatory and aesthetic requirements.
- **Contractor**: ensures that the procured reclaimed material satisfies the specifications put in place by the architect/ engineer and that its fitness for use has been validated to comply with performances specified in national regulations and standards. The contractor is then responsible for installing the reclaimed material abiding by the regulations and standards that control its installation.

A **Pre-demolition auditor** is involved before the extraction of the reclaimed material from a deconstruction project to perform a preliminary assessment of the reuse potential of materials present in a demolition project by identifying and documenting available material information based on his observations. The Pre-demolition auditor is asked to identify the types of materials present, their quantities, their apparent characteristics and condition, their current use and function. This actor can be accompanied by a **Reuse expert** to better advise on the procedure of demonstrating the reuse potential of existing materials. Note that the pre-demolition auditor can be at the same time a Reuse expert.

Reuse expert is asked to handle the evaluation of the fitness for use of the reclaimed material before and/or after its extraction. The Reuse expert then subscribes and supervises the necessary in-situ and laboratory tests to evaluate the required *essential* and *complementary* technical performances of the materials, while also relying on the available documentation.

Deconstructor handles the dismantling process that involves extracting the reclaimed material at the end of its first lifetime in the project, using controlled techniques and methods to avoid compromising its reuse potential. This actor is expected to follow deconstruction recommendations by the Pre-demolition auditor or the Reuse expert or even to possibly guarantee future traceability of the reclaimed materials, by labelling extracted materials with information related to material location or any deconstruction observations that may appear useful in later stages of material evaluation and testing.

The Deconstructor may be asked to carry out the important step of sorting the reclaimed materials in homogenous lots based on preliminary observations of their characteristics (sorting bricks by colour, by a degree of degradation…).

This actor may also be asked to carry out cleaning and packaging of the reclaimed materials and to prepare them for transportation off-site.

Reclamation dealer:

A reclamation dealer can handle different steps throughout the reclaimed material's journey in preparation for its second life. The reclamation scenario in place can widen or narrow the role of this actor, which can include the below tasks:

- Handling the sorting, cleaning, packaging, and transportation of reclaimed material right after deconstruction
- Ensuring the homogeneity of the reclaimed materials through different assessment methods
- Prescribing and carrying out laboratory tests to evaluate technical performances of reclaimed material
- Documenting the validated material performances and specifications that prove the material's fitness for use
- Ensuring the reclaimed materials are stocked in a safe manner
- Handling the processes of reselling and transporting the reclaimed material to a new owner or contractor

It is interesting to mention that some manufacturers handle themselves, through take-back strategies, the reclamation of their material at the end of its first lifetime.

It is crucial to point out the importance of the roles of the actors involved in the process of evaluation of fitness for use of a reclaimed material. The evaluation of the fitness for use is not necessarily limited to a specific actor or a specific stage, hence these responsibilities are to be well-defined at the beginning of each reclamation process.

Furthermore, the skills, reliability, and know-how of the actors involved as well as the coordination between them through proper documentation is particularly important. For example, in case of reclaimed bricks, the actor carrying out the deconstruction, cleaning or storage can be asked to detect and eliminate the defected bricks that seem unfit for use by showing a lack of strength, or to sort the bricks in homogenous batches of similar colour or other detectable properties.

	CLASSICAL SCENARIO	REUSE SCENARIO
Project Owner & Architect	Take design choices while make sure the materials integrated in their project meet technical, regulatory and esthetic requirements	Explore the possibilities of integrating reclaimed materials in their project while meeting technical, regulatory and esthetic requirements
Contractor	Procures and installs a material that complies with the specifications defined by the architect, engineer or project owner	Ensures that the procured reclaimed material, that he/she installs in the project, satisfies the project requirements, and that its fitness for use has been justified
Technical Controller	Validates the compliance of the materials and systems installed by the contractor with respect to project specifications and national regulations	Validates the compliance of reclaimed materials installed by the contractor and their fitness for use with respect to project specifications and national regulations
Material Manufacturer	Provides technical documentation related to the technical performances and specifications of the manufactured material	
Pre-demolition Auditor		Performs a preliminary assessment of the quantities of reclaimable materials in a deconstruction project prior to their extraction
Reuse expert		Justifies the fitness for use of the reclaimed material before or after its extraction: subscribes and supervises the necessary tests to evaluate the technical performances while relying on available documentation
Deconstructor		Carries out the deconstruction and extraction of the reclaimed materials following the guidelines set by the predemolition auditor or the reuse expert
Reclamation Dealer		Can handle any of the below tasks involving the reclaimed materials: • Buying and reselling • Sorting, cleaning, packaging, and transportation • Ensuring the aesthetical homogeneity of reclaimed of batches • Prescribing and performing tests to evaluate technical performances • Documenting material performances and specifications

3.2 Who is liable?

Just as it is for the distribution of the roles, the distribution of the responsibilities can be more sensitive in the case of a reuse scenario. In this chapter, we explore the main configurations, not necessarily exhaustive, of the responsibilities of the actors involved in potential reclamation scenarios. However, the distribution of responsibilities should be clarified at the beginning of each reclamation process between the involved actors due to the exclusivity of each project conditions.

In the **classical construction scenario**, the contractor, architect, engineer and the design office are responsible for serious defects endangering the stability or the solidity of the construction up to 10 years after delivery of works. Particularly, the architect is responsible for defects arising from design errors and execution errors that should have been identified by the architect's team. The contractor is responsible for construction and execution errors, while the engineer or design office is responsible for design errors they committed.

At the material level, the contractor is held responsible in front of the project owner for all materials installed by the contractor team in a project. After a contractor installs a new material, he or she is commonly entitled to provide a 10-year liability insurance to cover the costs resulting from any mishap that may occur to the executed work during this period. Consequently, if the contractor claims that an error in the declaration of the technical performance of the material is the cause of the accident, the material manufacturer may be deemed responsible if the latter has declared incorrect information in the material technical data sheet that has caused the accident.

The material manufacturers or suppliers are expected to have perfect knowledge of the material they put on the market and may be held liable for any hidden defects. They must also ensure to the buyer that the material complies with the intended use and installation. They have an obligation to deliver the material in accordance with the contractual specifications, and therefore, with the declared performance.

After having qualified a **reclaimed material**, dismantled it, and transported it to its reuse destination or to an intermediate site, a question arises in the absence of an important stakeholder, the material manufacturer: Who will guarantee the fitness for use of this material in its second lifetime? To answer this question, the responsibilities of each stakeholder in the reclamation process must be clearly defined.

We will start by pointing out the main steps of a reclamation process:

1. The safe and controlled deconstruction of the reclaimed material after the end of its first life
2. The transfer of the reclaimed material either to reclamation dealer or a refurbisher or directly to the project where it will be reintegrated
3. The process of sorting, cleaning and refurbishment of the reclaimed material
4. The verification of the technical performances of **the material to validate its fitness for use**

In this booklet, our discussion is mainly focused on the verification of the suitability for use of a reclaimed material, which is mainly addressed in step 4 but with a strong relation to the other steps as discussed in 2.4. However, the correct material prescription, installation as well as maintenance are not to be ignored in the reclamation process.

Establishing a clear distribution of responsibilities between stakeholders requires addressing the applicable reclamation scenarios. For that, we will discuss two main reuse scenarios:

SCENARIO 1: Reclamation through a reclamation dealer

SCENARIO 2: Direct project to project reclamation

3.2.1 SCENARIO 1: Material is reclaimed through a third-party reclamation dealer

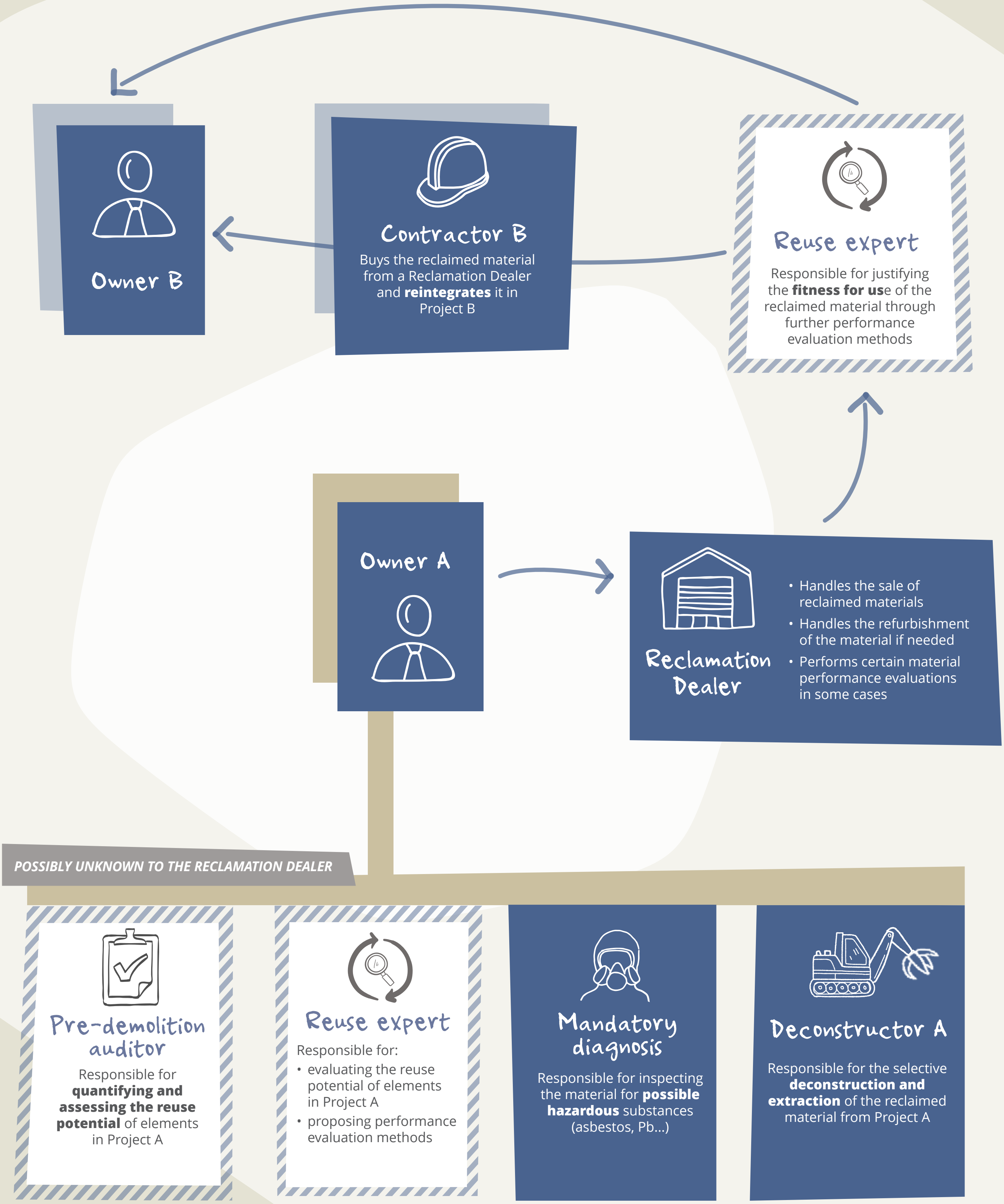
In this scenario, a reclaimed material has been extracted from its original project and sold or donated to a third-party reclamation dealer. It is no surprise that this process is commonly done with little or no information on the material or project history. However, it is also possible that the extraction of the material has been done through a controlled process in which a Pre-demolition auditor, a Reuse expert, and a Deconstruction expert were involved and in which the material's history and its technical performances were properly documented.

The Reclamation Dealer rarely proceeds to fully evaluate the material's technical performance and thus may not be capable of providing all necessary justifications of the material's suitability for use. In this case, the Reclamation dealer simply sticks to the role of a reseller who is only responsible for the light sorting, grouping and cleaning of the reclaimed materials. The reseller can guarantee a visual homogeneity and some aesthetic performances without declaring technical performances.

It is also possible that certain performances had already been verified during deconstruction if a *Pre-demolition Auditor* or a *reuse expert* were present, or that the *Reclamation Dealer* chooses to perform other *Technical Performance Evaluations*. In this case, each actor is held liable for the performance requirements they evaluate considering the reclaimed material's intended use and function. If many actors are involved in the evaluation process, the responsibility of evaluating the suitability for use of the reclaimed material is shared between them. When determining the actor responsible for the evaluation of a reclaimed material's suitability for use, it is important to maintain the traceability of each recorded evaluation of a technical performance: From the viewpoint of the buyer of the reclaimed material (Contractor B or Owner B) the intended use and function of the reclaimed material are both clearer. Hence, considering the available information provided by the reclamation dealer, the buyer decides which requirements the material must satisfy, the level of tolerance to be adapted, and whether complementary tests must be carried out. If the intended use requires more testing and evaluation, which is very common, the buyer can choose to consult a Reuse expert who acts as a technical qualifier to further justify the reclaimed material's fitness for use.

SCENARIO 1

Sale of reclaimed material through a reclamation dealer



3.2.2 SCENARIO 2: Material is reclaimed directly from project to project (applicable to same-project reuse)

In this scenario, Owner A sells the reclaimed material either to Owner B or to Contractor B. In the first case, Owner B passes on the material to Contractor B who installs it in Project B. If the intended use of the reclaimed material is known, specific tests and observations can be performed before the extraction of the material. If not, a general intended use can be specified and related technical performances may be evaluated and declared.

Ideally, a reuse expert is involved in the reclamation process. In this case, the verification of the fitness for use of the reclaimed material falls under the responsibility of the *Reuse expert* who may be accompanied by a *Pre-demolition Auditor* or may be himself the *Pre-demolition Auditor*. The *Reuse Expert* can intervene twice:

- at the pre-demolition stage to assess the reuse potential of the materials in Project A, and to propose the testing and evaluation methods that can justify their fitness for use.
- after the deconstruction to proceed with other evaluation methods that may have not been possible before deconstruction and to analyse available documentations and test results in light of justifying the material's fitness for use.

The Reuse expert can also be involved in defining the criteria of selective deconstruction and for selecting the representative samples of the reclaimed materials.

No reuse expert is involved

In the absence of a Reuse expert, the responsibility of the justification of the fitness for use of the reclaimed material falls on the buyers (actors of Project B or an individual buyer) who considering the intended use of the reclaimed material and the level of tolerance in relation to technical requirements (if existing), can decide which tests to carry out or whether to hire a reuse expert or a technical qualifier to handle proposing the required tests and verification methods. For example, individual buyers purchasing a reclaimed door for their house will not go as far as evaluating the acoustical performances of the reclaimed door.

In case of a construction project, it is precisely the project's design team that fixes this level of tolerance, while implicating other actors like the technical controller, the contractor, the insurance company, reuse experts, auditors and suppliers to define custom methods for the validation of the fitness for use of a reclaimed material, while guaranteeing that this operation is carried out with meticulous care. This operation is an exclusive and a personalised one that merely depends on each project conditions.

SCENARIO 2

Sale of reclaimed material from Project A to Project B

Owner B

Contractor B

Buys the reclaimed material from a Reclamation Dealer and **reintegrates** it in Project B

Reuse expert

Responsible for:

- justifying the fitness for use of the reclaimed material using the results of the verification methods
- verifying that the deconstruction has been properly carried out

Owner A

Pre-demolition auditor

Responsible for **quantifying and assessing the reuse potential** of elements in Project A

Reuse expert

Responsible for:

- evaluating the reuse potential of elements in Project A
- proposing performance evaluation methods

Mandatory diagnosis

Responsible for inspecting the material for **possible hazardous** substances (asbestos, Pb...)

Deconstructor A

Responsible for the selective **deconstruction and extraction** of the reclaimed material from Project A

4.

Conclusion: Toward the development of the reuse sector

The technical and regulatory frameworks for construction materials stem from industrial production and are not always suited to reclaimed materials. To be able to verify the performance of these materials, it is important not only to develop new methods, but also to consider the specific features of reusing them, such as knowledge about the history and origin of the materials, while taking account of specialised actors who contribute with their skills and expertise. The methods developed as part of the renovation process are also avenues to explore.

The issue of liability vis-à-vis declared performance (or not) is also a fundamental question that often places conditions on effective reclamation.
A clear dialogue between the different stakeholders concerned is essential since the diagram of responsibilities may vary from one project to another, depending on the actors involved. It is also important to determine what the good or bad practices are in terms of reclamation. This will enable the various actors to gain confidence more easily in the reclaimed materials, while clarifying the questions of liability and, from there, to insurance.

The obligation of CE marking for reused materials is also a subject up for discussion, but one that has not been broached in the context of this document. The study conducted by Rotor as part of the BBSM research project concludes in the current state of the law, CE marking is not mandatory for reclaimed construction materials [4]. However, there is no consensus yet as to the obligation or not to apply CE marking to reused materials.

So, studying the technical framework of reused materials would appear to be essential for increasing actual reuse. Other avenues may also enable reclaimed materials to be used more in the future: the design of buildings and other elements in order to make it easier for them to be dismantled and repaired, or the use of new tools such as passports for materials or the BIM to make it easier to pass on technical information.

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