Platform CB'23 – Guide

Quality assessment and assurance when reusing products from existing structures.

Version 1.0 – 29 June 2023

Platform CB'23 – Future reuse

Preface

The need for a transition to a circular economy is common knowledge. An important step along the route is the reuse of products from existing structures. This means reusing elements or construction products in another structure. So a project from which products are released becomes as it were the builders merchant for another new-build or reconstruction project: demolition projects become donor projects.

Working in this way will require a switch away from the current system. The construction and demolition processes will have to be changed in order to enable reuse.

An important aspect of reuse is the quality assessment and assurance of products and this is the subject of this guide. The quality of donor products will need to be assessed prior to reuse, and then assuring that quality throughout the process will be important.

Until now, there have been few documents that address and give advice on quality assessment and assurance in the case of reuse. This document is now doing exactly that for different types of elements and construction products and for all steps in the reuse process. The advice is illustrated with sample projects.

In writing this guide, our goal is to inspire people and advise them on how to optimise the reuse process and ensure that reuse becomes the new standard in the future. To achieve this, the guide will need to be further developed and regularly updated given the rapid evolution of the reuse market.

Platform CB'23

Platform CB'23 (Circular Construction 2023) has committed to drafting agreements on circularity in the construction sector. The platform brings stakeholder parties (including market parties, policymakers and researchers) together to talk to each other and arrive at broadly supported agreements. To do so, they work in different action teams. This document was drafted by the *Toekomstig hergebruik* action team.

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1 Introduction

1.1 Background

We are moving towards a new way of building structures: circular construction instead of linear construction. Linear construction aims to build as efficiently as possible and at the lowest possible cost. However, this system has been shown to be unsustainable. If we want to ensure our planet remains liveable for generations to come, we will need to make a lot of changes. The construction sector will not be exempt. This is motivating more and more people and organisations to build in a circular way.

Reuse is an important topic in circular construction. By reusing products, we create less waste and use fewer raw materials. There are, of course, more topics that are important for circular construction: environmental impact; building less and with fewer materials, or using "bio-based" materials; increasing the adaptive capacity of structures (through overdimensioning, among other strategies); and extending the service life of structures.

Products from existing structures are already being reused, albeit on a small scale. However, reusing such products is currently more difficult than enabling reuse in the future, since data on existing structures have often been insufficiently recorded and because many existing structures have not been designed with reuse in mind. Products in existing structures are not detachable, for example, and this sometimes makes them more difficult to use in another structure.

If products from existing structures are to be reused, they must be of good quality and preserve their good quality, e.g. they must have good mechanical properties and a long residual service life. Products will only be reused if their quality can be demonstrated (assessed) and assured.

This guide provides a framework for the quality assessment and assurance of products to be reused from existing structures. Initiatives for specific product groups for this subject have been launched, but since there is no overarching framework fewer products than possible are being reused. Where products are reused now, this is often in applications of a lesser value, since it is difficult to assess and assure the quality of reused products. Through this guide, we aim to contribute to the increased reuse of products from existing structures by parties in the construction sector, and to an increased awareness among those parties of what they can expect from such products because the product quality has been properly assessed and is properly assured.

1.2 Scope

This guide is intended to be applied to:

- the entire construction industry (the buildings sector and the civil and hydraulic engineering sector);
- the elements and construction products from existing structures (we are using the umbrella term "products" for these levels of scale) – see Figure 1;
- structural and non-structural products;
- all product groups in construction;
- the entire reuse process: from the initial intention or stocktaking to application in the new structure.

Level of scale	Examples	
	Buildings sector	*Civil and hydraulic engineering sector*
Area	Campus including greenery	
Complex	Campus	
Structure	Residential module, flexible home	Flyover, bridge
Element	**Façade, roof or floor element**	**Bridge deck, abutment**
Construction product	**Window frame, door frame, window, door, grille, cavity**	**Prestressed concrete beam**
Material	Insulation board, timber rails	Concrete, steel
Raw material	Timber, steel, insulation fibres, gravel, sand	Sand, gravel, cement, slag

Product for reuse

Scope of the guide

Figure 1 – Levels of scale of the scope of this guide

This guide focuses on the levels of scale of elements and construction products. However, knowledge gained from this guide can also be used when assessing materials or structures (including temporary structures) for a subsequent cycle.

The emphasis in this guide is on structural products. These are the products for which the need for quality assurance and assessment is greatest. This is because the quality of structural products strongly impacts on the quality of a structure: a substandard structure will pose great risks. Generally, the quality of structural products is also harder to assess and assure than that of non-structural products. Having said that, the guide can also be applied to non-structural products.

For the purposes of this guide, we have adopted a broad interpretation of the term 'quality'. A product for reuse is of good quality if it meets all the functional requirements for the new application, can be installed in the new structure within the boundaries of current legislation and regulations, and can be used for the desired period.

This guide addresses both the "hard", technical side and the "soft", human side of quality assessment and assurance. The hard side encompasses technical quality investigations and associated standards. The soft side relates to the people and processes needed to assure the quality. This covers the way reuse is viewed, people having the right attitude, and matchmaking between the demolition and the construction sides.

In this guide, we use several different terms for the demolition and construction sides, since the most appropriate terms intuitively speaking vary from context to context. Table 1 lists these terms.

Table 1 – Terms for the two sides of the reuse process

Structure from which the product has come	Structure in which the product is applied
Push (materials enter the market)	Pull (materials are withdrawn from the market)
Donor project	Adoptive project
Demolition	Construction

This guide provides a general framework for quality assessment and assurance that can be used to make agreements on the quality assessment and assurance of specific product groups. This guide also discusses the outlines of studies of the quality of products of the four most commonly used structural materials (concrete, steel, timber and masonry), since the sector needs them the most. However, these quality studies will have to be defined in more detail for product groups of those materials as well.

The guide is intended for clients (on both the demolition and the construction sides), builders, demolition companies [1], intermediaries and parties providing advice. The guide also contains recommendations for policymakers.

1.3 Simplified system

For legibility purposes, this guide assumes a somewhat simplified system for reuse in terms of roles and phases. In practice, every reuse project will be different and so roles and phases may be different as well.

This guide assumes the following roles:

- client on the push side;
- demolition company;
- client on the pull side;
- builder.

In practice, the role of demolition company is sometimes filled internally, particularly in the civil and hydraulic engineering sector. In practice, intermediaries between the push and pull sides can also play a role.

This guide assumes the following phases on the push side:

- current/start;
- preparations for dismantling;
- dismantling;

This guide assumes the following phases on the pull side:

- current/start;
- design;
- preparations for new construction;
- construction;
- use.

Matchmaking and transportation and possibly repair and storage take place in the meantime.

These phases are shown in Figure 2. In practice, some phases of reuse projects are redundant or take place simultaneously.

1.4 Development of the reuse market

Two types of products should be distinguished in connection with reuse:

- common, standardised products in high demand. Examples are doors, door or window frames, and steel sections;

[1] Where we use "demolition company", this can also be read as "demolition contractor' or "dismantling company". In this guide, we use "demolish" and "demolition company" because these terms are more commonly used. However, from the perspective of circular construction, "dismantle" is the preferred term.

- design-specific products made to fit in the donor project. Examples are concrete beams, balcony railings and complete façades.

At present, active matchmaking is required for both types of products, as evidenced by successful reuse projects. This has implications for the quality assessment and assurance process. To align with the real-life situation of the next few years, it was decided that the soft side of this (see 1.2) should also be covered in this guide.

If the reuse market develops further and supply and demand for reused products grow, the need for matchmaking will decrease for common products (see 3.5). Observations on matchmaking from this guide will then be less or no longer applicable to these products.

1.5 Structure of this guide

Figure 2 lists all the phases of a reuse project, both on the demolition (push) and construction (pull) sides. This figure also shows how the chapters of this guide relate to these phases. In outline, the chapters are arranged chronologically.

Chapter 2 describes the processes from both sides (push and pull) before the other side (pull or push) becomes relevant and before quality studies are carried out. This mainly concerns the organisation's view, reuse aspirations and the initial stocktaking. The outlines of what quality to assure will already become clear at this point.

Chapter 3 describes the "soft side" of the next phase, i.e. the matchmaking process, which ends in sale/procurement. A good matchmaking process is a form of quality assurance: it ensures that the pull side receives the required quality and it leads to the arrangements and collaborative processes needed to assure that quality. The matchmaking process also shows at what points in the process quality studies (the "hard side") are needed.

Chapter 4 describes the "hard side" of roughly the same phase as chapter 3: the quality studies. The outlines of the studies that can play a role for the four most commonly used structural materials are described.

Chapter 5 is about the process from demolition/dismantling to the use of the product in the new structure. This is the phase in which it is assured that the agreements made are fulfilled. Parties also need to prevent loss of quality.

Chapter 6 contains inspiring and instructive practical examples of quality assessment and quality assurance processes in reuse projects.

Chapter 7 contains recommendations for further developing quality assessment and assurance, for policymakers and other parties.

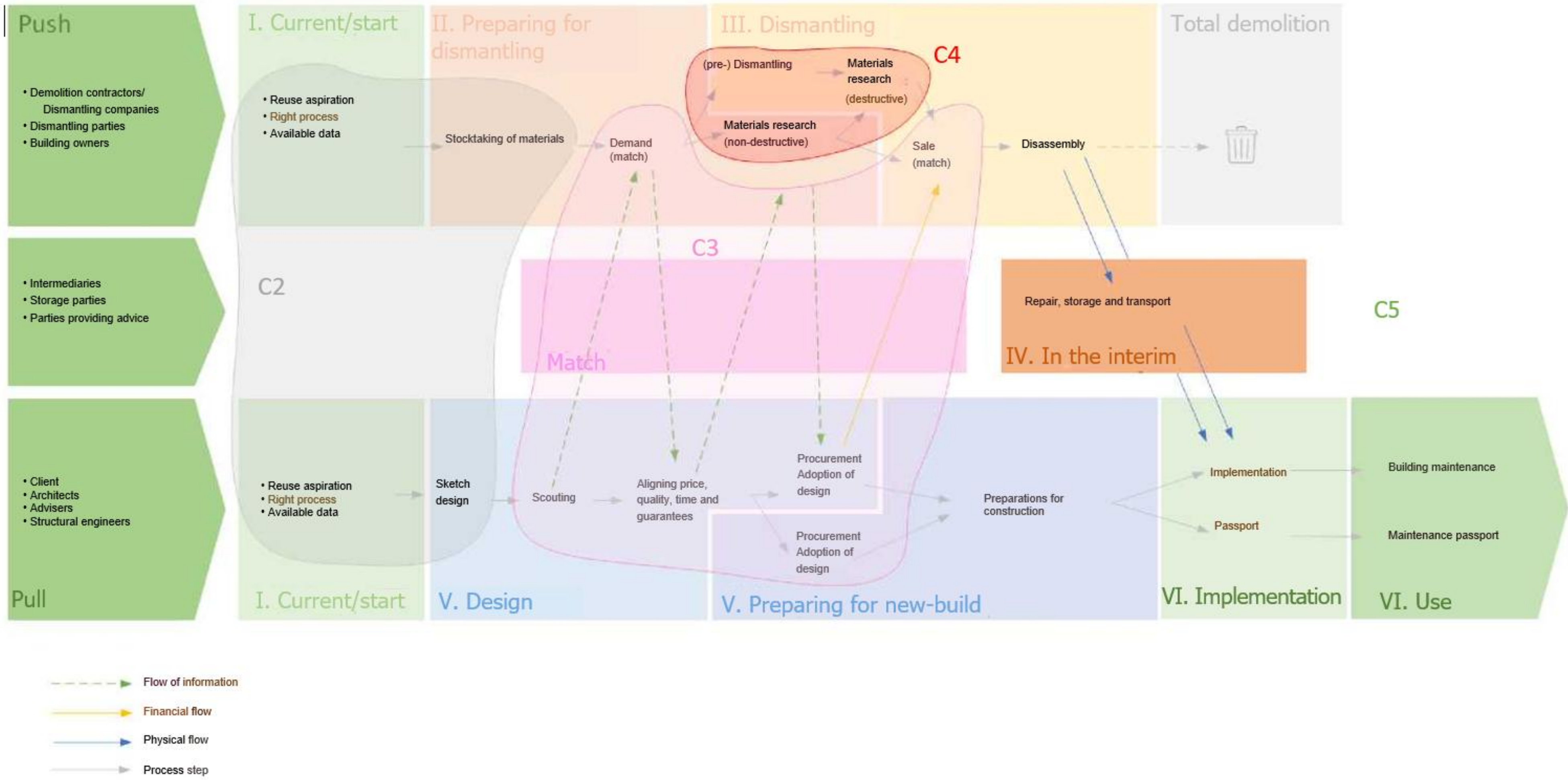


Figure 2 – Division of the guide into chapters

2 Preliminary pathway

2.1 Introduction

If organisations want to contribute to reuse, they do not start the matchmaking process until the necessary steps have been taken on both the push and pull sides, with the other side (pull or push) not yet playing a role. This chapter describes those steps, including the vision at the organisational level and the initial stocktaking at the project level. This serves as the basis for the matchmaking process described in Chapter 3.

In general, the sooner you start on the preliminary pathway, the better, as for some products it can take a long time to clarify whether, how and by which party they can be reused.

Figure 3 shows where Chapter 2 is positioned in the reuse pathway.

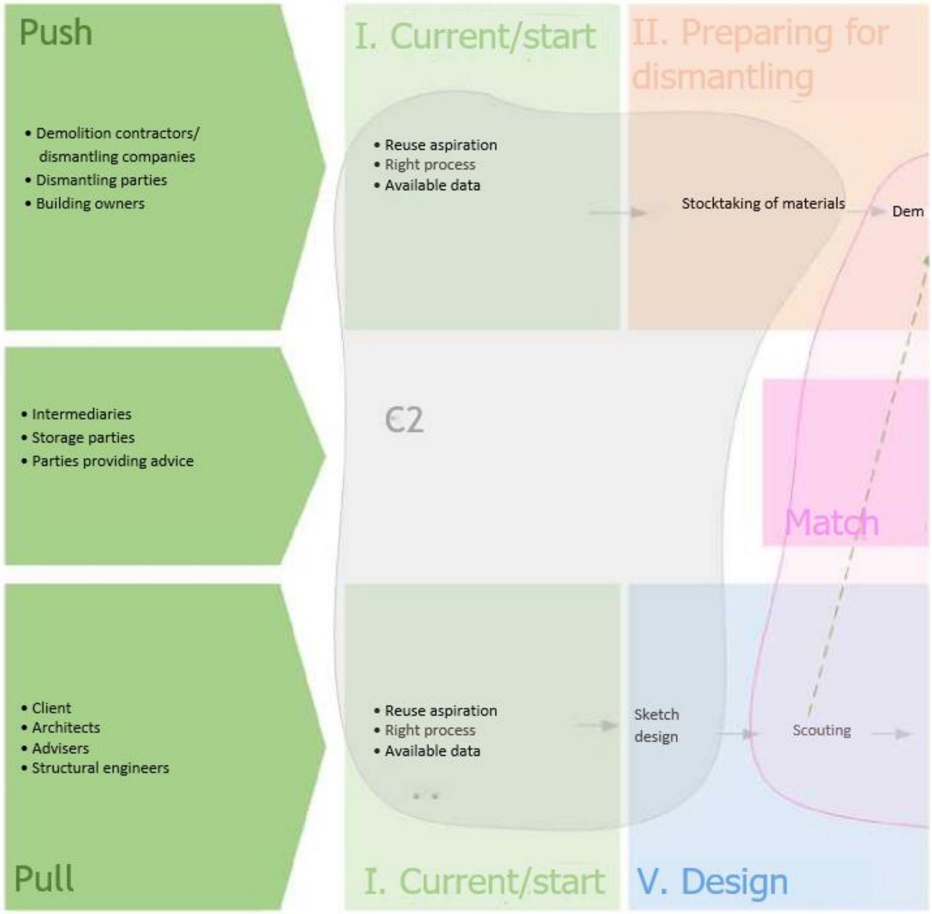


Figure 3 – The position of Chapter 2 in the reuse pathway

2.2 Impact

An organisation wanting to contribute to reuse does so in order to contribute to the three goals of circular construction (see Platform CB'23, 2022):

- to protect material stocks;
- to protect the environment;
- to retain existing value.

Organisations should embed circularity and reuse in their vision statements. This is done by formulating how the organisation can, and wants to, contribute to these three goals. Of course, this will differ from one organisation to another. Think about where the biggest gains can be achieved by your organisation and then look beyond only reuse. Examples of how more gains can be achieved are: using fewer materials, using bio-based materials, extending the service life of structures, or making structures more adaptive.

To formulate a good vision in respect of circularity, information is needed, e.g. on your organisation's current CO_2 emissions or the number of products or structures your organisation owns and purchases.

All projects where reuse is relevant should ideally be guided by your organisation's vision. In your vision statement, you define the *quality* that you aspire to in those projects. You cannot assess and assure that quality if this vision is lacking. For example, you will then know what KPIs to formulate or what requirements and criteria to use in requests for proposals.

2.3 People/attitude

If your organisation wishes to contribute to reuse, attention should be paid to the people and attitudes needed for this, because reuse projects often necessitate straying from the beaten path and deviating from 'traditional' roles. This is because reuse has not yet become the norm. Reuse projects are not necessarily more expensive or more complicated than linear projects, but they are different, also where quality assessment and assurance are concerned.

For reuse projects, preferably select people from within your own organisation who:

- are intrinsically motivated for circular construction and have an affinity for reuse (ideally they will also have experience in this);
- are keen to do and learn new things;
- can handle unexpected situations and think in a solution-oriented way.

You can assess whether someone has these qualities in several ways – by asking the person what they would do if something is suddenly found not to be possible, for instance.

If it is difficult to find suitable people from within your own organisation, consult the *Circular Procurement Guide* (Platform CB'23, 2021), which contains recommendations to ensure that more employees develop an affinity for circularity. Successful pilots can also play a role in motivating employees.

For successful reuse, it is important that project teams are given proper guidance and support. New project teams cannot do this on their own.

Decision-makers in your organisation need to support reuse. For example, if a decision-maker assumes that reuse is time-consuming, expensive, dangerous, unsightly or not feasible, a reuse project is unlikely to be successful.

It is also wise to pay attention to the people and attitudes of the parties you work with (see 3.4).

2.4 From the client (push)

2.4.1 General

If you are the client on the push side and you want to enable reuse, you will need to have an overall view of your own portfolio of structures. You achieve this by properly recording the data relating to your structures, for instance in passports for the construction sector (Platform CB"23, 2022b).

You will need to have a good overall view of the structures you possess, along with a broad understanding of the quality of those structures and the products used in them, and will need to know which structures will be demolished when. Reuse requires good planning. A reuse project that is started without proper preparation is less likely to be successful.

You can use the data on your portfolio of structures to perform reusability scans, or have them performed by another party, on a regular basis. Reusability scans map which products are potentially suitable for reuse and what information is relevant for potential buyers. Take a low-threshold approach to the performance of a reusability scan without carrying out intensive research at this stage (see chapter 4). Also look for opportunities to reuse products in your own structures. This simplifies the quality assessment and assurance process.

Take good care of structures in your portfolio in order to extend their service lives, retain quality and value, and increase the chances of reuse. You do this by using the structure carefully, carrying out maintenance and repairs in good time and preventing buildings from being left empty (because of cold and the risk of break-ins).

2.4.2 Per project [2]

If you are the client on the push side, you formulate the donor targets for each project, preferably based on your organisation's view of circularity and reuse (see 2.2.). You include this objective in the scope of the project – in the schedule of requirements (SoR), for instance. A common donor objective is to reuse as many products as possible, and with the highest value possible, within the framework of the project.

Gather information early on
Gather information about the structure and the products within it as soon as possible. As a minimum, this should include information on:

- mandatory studies into harmful substances (asbestos, chromium-6, etc.);
- the original construction and the types of materials and connections used in the original construction;
- the structure's usage and conversion/renovation history.

Section 4.2 contains an extensive reuse assessment list. Study what information about which parts of it is already relevant at this stage.

Documents that can contain relevant information for reuse include:

- a passport for the construction sector (if available);
- LCAs drawn up on completion;
- construction drawings and contract documents relating to the original construction and any alterations;
- specifications and the manufacturer's original product sheets;
- drawings (including drawings of architectural, structural, fire-proofing and electrical aspects and of climate control installations). Examples are floor plans, cross-sections and detailing;
- construction reports on any modifications carried out;
- inspection reports;
- damage reports;
- photos of the structure (interior and exterior in the buildings sector);

[2] The contents of this section are partly based on Repurpose 2022.

- contact details of the structure's last manager. They often know from experience which products will still be in functional order.

Select a suitable demolition company early on
For dismantling/demolition, select a demolition contractor with an appropriate vision (see 2.2) and attitude (see 2.3), and with experience of dismantling products for reuse or of having products dismantled for reuse. It is also important that the demolition company has an employee responsible for selling released products. Ask the demolition contractor about their vision in respect of reuse for the specific project (opportunities, working method) and about the financial aspects (is the sale of products for reuse part of the price or does settlement take place after the sale?).

Give the demolition company sufficient time and information for the preparation of an offer. Share any available information on the structure with the demolition company (see above) and have the demolition company view the structure early on and for as long as necessary. A half-hour viewing is usually insufficient in terms of assessing whether there are any marketable products in the structure. Preferably give the demolition company two months to prepare its offer.

Select the demolition company as early on in the process as possible. This will increase the probability of a match for reuse and sale. Preferably, after awarding the contract, give the demolition company at least three months for dismantling and sale.

If it turns out there is too little time to sell products from the structure, select a demolition company with its own yard from where these products can be sold and, if relevant, involve a specialised demolition management agency. Choose this solution only if there is no alternative. Selling straight from a structure often leads to better results because no preliminary investments are needed for dismantling, storage, and online or offline sale, or for disposing of any products that have not been sold. Furthermore, if products are sold from a yard, a demolition company will only dismantle products for which there is clearly a good chance they will be sold. A demolition company will not easily sell design-specific products from a yard (see 1.4), reducing the likelihood of reuse.

In all cases, make sure the actual sale is verifiable. The Dutch Circular Demolition Project Verification Scheme (*Verificatieregeling circulair sloopproject* - SVMS, 2023) is one way of doing this.

2.5 From the demolition company (push)

Any demolition company wanting to enable reuse will need to specialise in this. You can do so by gaining experience in dismantling products for reuse yourself, or having another party do this for you, and selling products for reuse. Building a network for collaboration and for selling released products is also important. Where possible, build a local network to minimise transportation of reused products. Also look at other industries: materials that are considered to be waste in one industry can be useful input material for another.

Demolition companies should make sure their clients give them sufficient time for a reuse project (see 2.4.2). Try to talk to the client as early on as possible and ask for sufficient time to inspect a structure, prepare an offer, dismantle a structure and sell products from that structure. Also, always ask clients for all the available information on the structure. Discuss whether there are any requests or opportunities for the reuse of products on site.

2.6 From the client (pull)

If you are the client on the pull side, you formulate the adoption targets for each project based on your organisation's view of circularity and reuse (see 2.2.). Limit the number of products from reuse if it is the first time that the team in question is working on reuse. If an inexperienced team wants to do a lot all at once, the risk is that they will actually achieve very little. An experienced team can apply the 80/20 rule to impact (see 2.2). This means that you study which 20% of the products jointly cause 80% of the impact (e.g. in terms of material stocks or emissions).

Make one person, with the right attitude (see 2.3) and the right authorities, responsible for progress on the adoption targets.

Allow plenty of time in the schedule and ascertain what should be reused as early on in the process as possible. Finding a match (see chapter 3) and conducting a quality study (see chapter 4) often take time. Reuse projects come with a higher probability of unexpected situations and setbacks too. If you cannot find an appropriate reuse match, the design may have to be modified, for example.

Involve all key parties early on. Key parties will, of course, include a designer/architect with the right attitude (see 2.3), but also end users (so they know what to expect), the municipal building aesthetics committee ("welstand" in Dutch) to avoid any delays, and the competent authorities.

2.7 From the builder (pull)

A building company that wants to enable reuse needs to specialise in this. Gain experience with reuse projects, keep your knowledge up to date and build a network in your industry. A network is important for collaboration and expertise and for procuring released products for reuse (see 2.5).

Work with partners who have the right attitude (see 2.3.). These will be partners in the chain who are willing to share the risks in reuse projects (see also 3.2) and clients willing to pay the actual costs of reuse, or to accept certain risks.

In quotations, show clients the difference between the cost of a new product and the cost of a product from reuse. Take partners who have no affinity with circular construction along with you in the transition to circular construction.

3 Matchmaking

3.1 Introduction

The next phase starts when a party on the push or pull side wanting to reuse products has taken the preparatory steps described in Chapter 2. It is the matchmaking phase in which demand (pull) and supply (push) come together. It continues up until the point at which the product to be reused is sold/purchased. The expectation is for the matchmaking phase to become less relevant in the future, or even to become redundant (see 1.4).

The matchmaking phase has a "soft", human side relating to people and processes (in terms of working together and timing) and a "hard", technical side relating to products and quality studies. Both sides are equally important if reuse is to be successful. The matchmaking process is as strong as its weakest link.

This chapter describes the soft side of the matchmaking phase (see Figure 4). The hard side is covered in Chapter 4, but in this chapter we do refer to the points in the process at which the quality studies described in Chapter 4 can play a role.

A good matchmaking process is a necessary form of quality assurance for design-specific products and for standard products, as long as their reuse market is small (see 1.4). Matchmaking ensures that the pull side receives the required quality and provides for the agreements and collaboration processes needed for quality assurance, which currently need to be as efficient as possible.

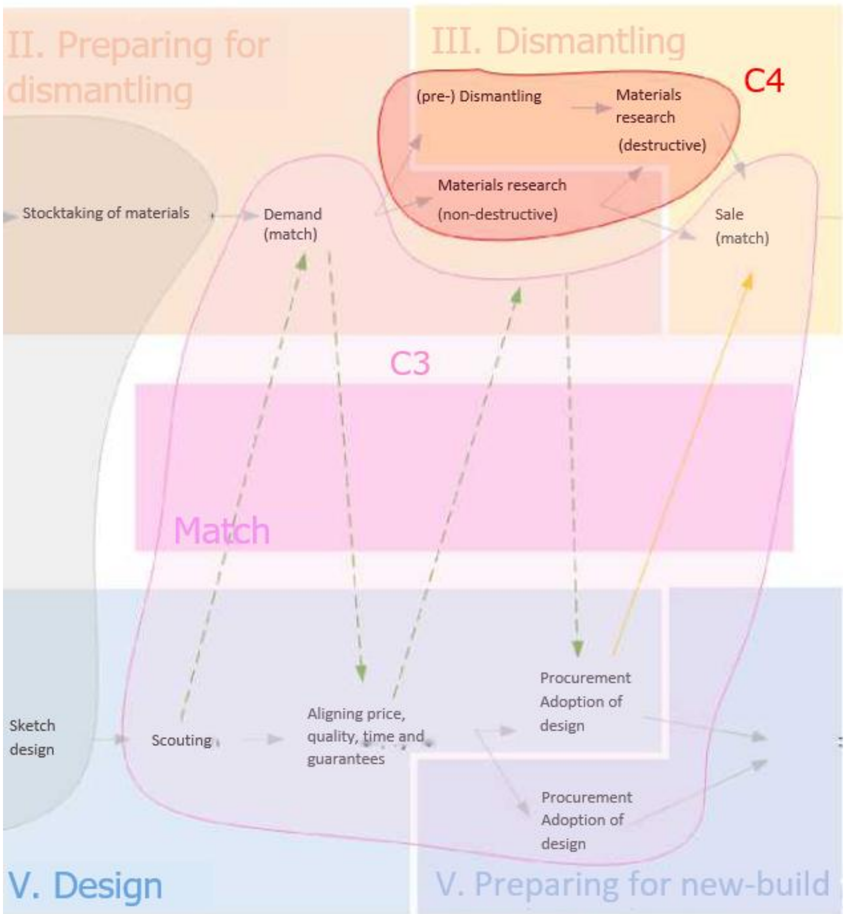


Figure 4 – The position of Chapter 3 in the reuse pathway

3.2 Matchmaking from the push side

3.2.1 Advertising the products on offer

Matchmaking from the push side starts once the client has selected a demolition company (see 2.4.2). The demolition company (or intermediary) advertises the products to potential buyers. You can do this through your own network or through reuse marketplaces or platforms.

Once you have found a potential buyer for a design-specific product, additional information is often required in order to establish the quality of the product. Since expensive and time-consuming quality tests in a laboratory (see Chapter 4) will have to wait until a potential buyer has been found, further research is often required during the matchmaking phase (see 3.2.2).

Some products need to be dismantled or pre-dismantled before they can be sold. This is often the case with products whose suitability for reuse can only be demonstrated by destructive testing. This is primarily a good option if the aim of the project is to offer as many products for reuse as possible (and cost considerations are less important).

3.2.2 Further research

If further research is needed, reviewing the planning schedules of both sides (push and pull) first is advisable. If either of the two sides has no time for further research, there will be no reuse match.

If there is time for further research, first looking for information that is easy to retrieve before looking for information that is harder to ascertain is advisable. Easily retrieved information sometimes shows that a product is not satisfactory after all. This means that unnecessary research costs can be avoided.

An example of information that is easy or hard to retrieve: climate control cabinet
If no illustrations are available for a reusable climate control cabinet, they will be easy to retrieve, but the quality of a climate control cabinet will be harder to establish.

For information that is harder to retrieve, it is important that proper agreements are made on what will be researched, who will carry out the research and who will pay any costs involved (see also 3.4). Such costs might include laboratory testing costs, for instance. The buyer and the seller could split the research costs. You could also agree that the buyer will only pay for the research costs once the product is found to meet the adoption description (see 3.3.1).

Include all costs when making agreements relating to costs. Examples are costs for checking and upgrading the product and logistics.

3.2.3 Sales

If the pull side decides to buy the product (either after or without any further research), the demolition company draws up a quotation. The quotation should include as a minimum:

- known product information with images;
- agreements made (on warranties and responsibilities, for example);
- any product defects, along with photos. Be specific and clear in this respect in order to avoid the buyer regretting their purchase or being faced with unwelcome surprises.

3.3 Matchmaking from the pull side

3.3.1 Scouting

Matchmaking from the pull side starts with "scouting" for promising products. For this, draw up an adoption list that includes the following information for each product to be scouted:

- the **description** (specifications) of the product;
- the **best point in time** (timing) for scouting;
- who is **responsible** for the purchase.

The products on the adoption list may vary depending on the project phase.

An example of a changing adoption list: an entire industrial building
The adoption list might feature an entire industrial building during the preliminary design phase. If it is clear that an entire industrial building cannot be found, steel portal frames and a building envelope can be added to the adoption list.

Description
Describe the requirements to be met by a product to be reused. Formulate a description that matches the adoption project ("narrow"), but that will result in as many products as possible ("broad"). Do not formulate any unnecessarily "stringent requirements". The recommendation is to draw up a description focused on function so that any non-standard solutions can be a fit for the description as well. An open, but not too open, description, works best.

An example of a description: specification of doors
A specification that reads "50 doors" will result in many matches, but these will include many doors that will not fit. A one-page specification for 50 doors is unlikely to yield any matches at all.

Timing
Timing is also important when scouting for products. Try to strike a balance between the following two factors:

- Scouting *early on in the process* offers the advantage of increasing the likelihood of a match and allowing time for an alternative solution (adjusting the design, buying the product new) if no match is found. Scouting early on is a particularly good idea for products that will have a major impact on the design to be developed.
- The advantage of scouting *later on in the process* is that the period up until the point of application in the new structure will be shorter (shorter storage time, less risk of damage). Scouting later on is particularly useful for construction products that have little or no effect on the design.

Example of timing: timber beams
Scouting for timber beams for internal walls during the preliminary design phase is not advisable. If you do find beams during this phase, you will need to store them for an unnecessarily long time. Waiting until you would be forced to order new beams (made of primary material) in order to meet the schedule is also unwise. If you are unable to find a match, the actual construction phase will be delayed. A good time to scout for timber beams is a couple of months before you would otherwise need to order primary material beams.

Responsibility
Make agreements with the builder on who scouts for and purchases specific products. It is especially important to do this if products are to be procured as early on as in the design phase (preliminary design phase). At that point, one of the parties will need to have a budget for this. If no contractor or subcontractor who can be responsible for procurement is involved, the client often handles the procurement itself and eventually delivers it to the contractor.

3.3.2 Procurement

The person or team responsible for procurement looks for suitable products in their own network and on marketplaces, based on the adoption list. If a product on offer seems to match the adoption description, contact the seller. If there is a match, some additional research will often be needed to establish the quality of the product before purchasing it. The process for this, for both the push and the pull sides, is described in 3.2.2.

Before purchasing, always ask the seller for a quotation. Specify clearly what should be included in the quotation (see 3.2.3). Make proper agreements as to who will bear what responsibility for the product (e.g. for logistics) until it is used in the new structure. Do not agree to any quotation until it lists everything agreed. This minimises the risk of any setbacks.

3.4 Aligning push and pull

The probability of successful reuse is higher if the push and pull sides:

- **align their planning schedules as soon as possible** or even integrate them: this will accelerate the process because quality studies (see Chapter 4) can be carried out earlier;
- **make clear agreements** on who is responsible for what, who pays what and how quality is assessed (see 3.2.2, 3.3 and the list below);
- **work together** closely and **share information.**

Figure 5 contains a chart that can be used to align the push and pull sides. Figure 5 ends in the dismantling plan: the starting point of Chapter 5.

Different agreements can be made as to who is responsible for quality:

- The client on the pull side, builder/contractor and demolition company (supplier of the products to be reused) **jointly** take responsibility for quality. This increases mutual trust because the client on the pull side knows the origin of the product and the journey travelled by the product.
- **One person or party** takes responsibility for the quality. This can be the main contractor or subcontractor (as in linear new-build projects [3]), but there are also projects where this is the client on the pull side or an intermediary, such as a specialist dealer.

[3] Dutch Building Quality Assurance Act (Wet Kwaliteitsborging voor het bouwen - Dutch national government, 2023) makes the contractor liable for any defects that cannot be attributed to others, such as the architect or structural engineer, if they are not the contractor's responsibility.

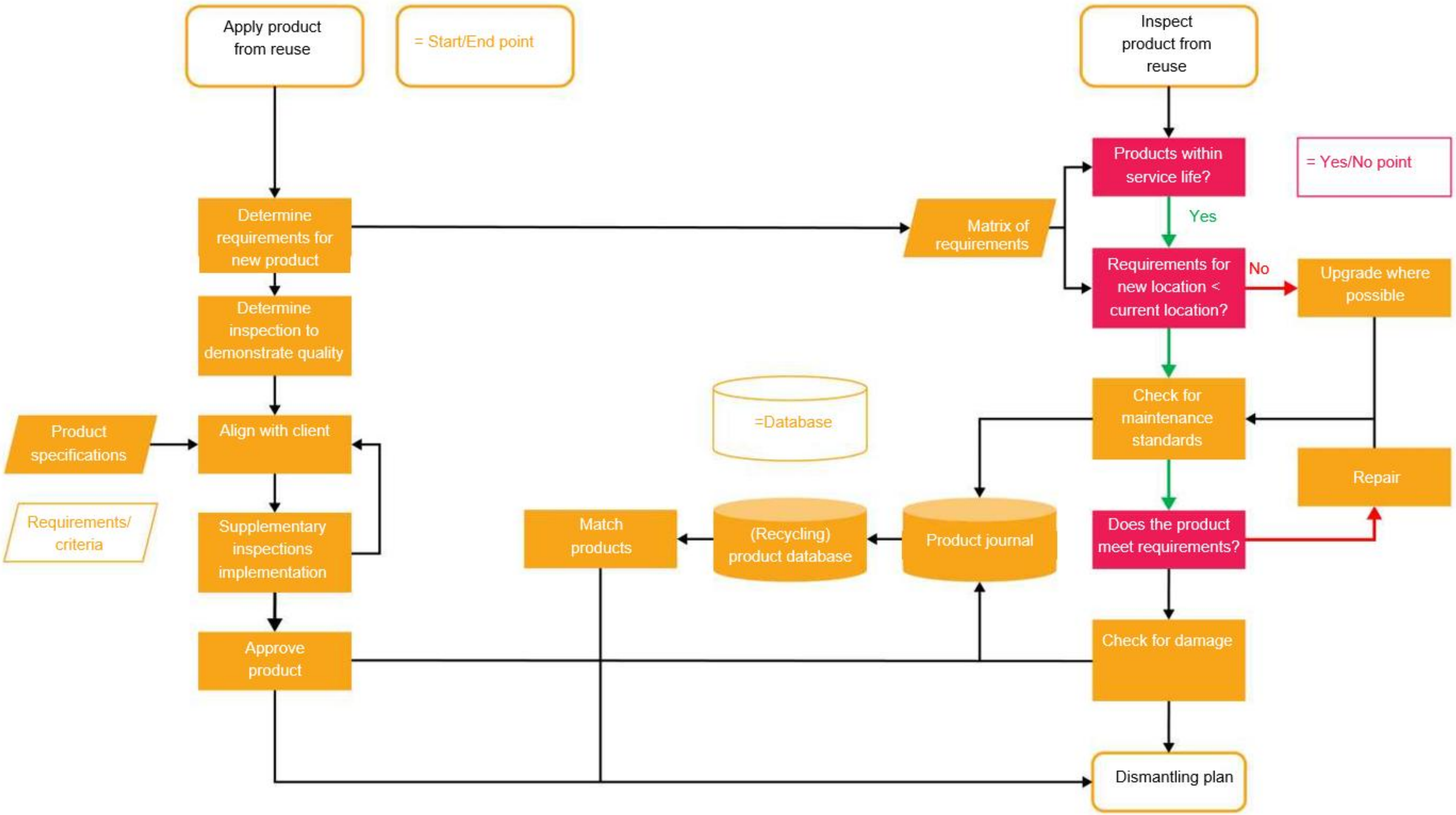


Figure 5 – Chart showing the alignment between the push and pull sides in the matchmaking process

3.5 Trade via intermediaries

Matchmaking will continue to be needed for design-specific products. A market for common, standard products for which there is high demand will evolve, making matchmaking redundant or making matchmaking a process that automatically takes place via specific parties or platforms (1.4).

A product for reuse can then be dismantled or removed and assessed without the adoptive structure being known. The product is then purchased by an intermediary who sells it from a storage location, similar to the way in which new products are sold.

4 Quality studies

4.1 Introduction

During the matchmaking phase (Chapter 3), and sometimes during a brief period after that phase, quality studies are often needed to determine whether the product to be reused meets requirements. This is the "hard" side of the matchmaking phase. This chapter takes a closer look at this hard side. Figure 6 shows where this chapter is positioned in the reuse pathway. What studies will be needed will depend on several factors, including the product description of the adoption project (see 3.3.1) and the information already available.

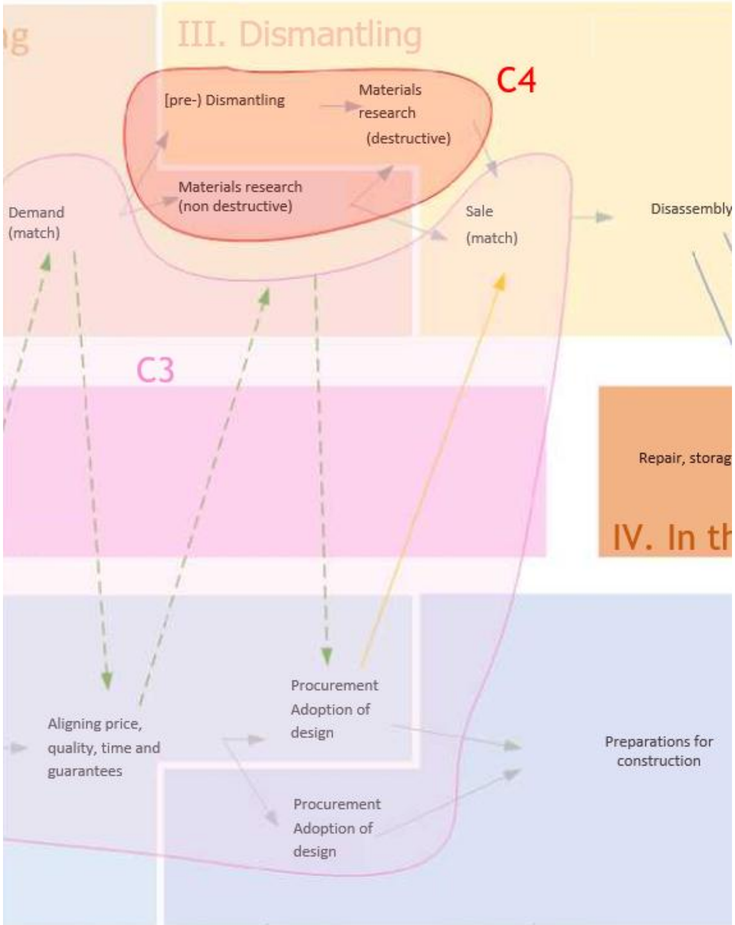


Figure 6 – The position of Chapter 4 in the reuse pathway

This chapter starts with an assessment list containing every aspect that may require quality to be studied (4.2). This list is suitable for structural and non-structural products. We then address quality studies for structural products (4.3 - 4.7), discussing quality studies for the four most commonly used structural materials.

The emphasis is on structural products because they are what the sector needs most (see 1.2). Reuse of these products generally requires more information and therefore more research than the reuse of non-structural products.

4.2 Assessment list for reuse

Table 1 - Assessment list for reuse[4] of products

Intended purpose	**Assessment of whether a product on offer is suitable for reuse in the adoptive structure[5]**		**Inspection/assessment**
	Quality studies to possibly be carried out	*Explanation with examples*	
Impediments for reuse of product	Assessment of the condition of the product (for example degradation of the material) in order to be able to make a statement on preservation for reuse in relation to building regulations (2012 Dutch Building Decree and, with the introduction of the Dutch Environment and Planning Act, the Environment Buildings Decree (Besluit Bouwwerken Leefomgeving)	Visual inspection for, for example, corrosion, wood rot, cracks, bending, plastic deformation, carbonisation, chloride penetration and fire damage	Notes
	Investigations into past actions	For example, by sawing recesses	Listing
	Assessment of feasibility of repair	Processing possibilities, also by refacing or adhesive reinforcement, for example	
	Research into the presence of prohibited and toxic substances, if emissions are relevant (see 5.1.1.)	For example: asbestos, heavy metals (including chromium-6), PAH and PCB	Listing
	Research into the feasibility of removing or shielding prohibited and toxic substances	The result may constitute a definitive impediment	Notes
	Assessment of aesthetic quality (condition, colours and shapes)	Ask the question: how critical do you want to be when it comes to reuse – in respect of colour, for example	Add photos
	Research into the feasibility of adaptation (refurbish, remanufacture)		

[4] This refers to the R principles of reuse, repair, refurbish, remanufacture and repurpose.

[5] This assessment list can also be used to plausibly demonstrate that a product for reuse meets the technical requirements of the 2012 Dutch Building Decree (Dutch national government, 2012).

Feasibility of the product for intended reuse	Assessment of dimensions, possibly with modification (spatial integration)	Indirect testing against the usability requirements of the Dutch Building Decree 2012, for example timber beam lengths and door heights	
	Research into the feasibility of repair	For example, increasing the height of an old door	
	Research into the dismantling method (see 5.1)	For example, sawing, screwing, cutting and pulling	
	Assessment of detachability	For example, the consequences of sawing and breaking	
	Assessment of the feasibility of transport (transportation to the adoption project, see 5.2)	Both technically and financially	Kilometres
	Surface area, weight and shape of the product	Gives an idea of the type of transport needed (for example, escorted transport)	
	Number of transports and transport mode	For example, transport can only be done at night	
	Transport costs	Depending on number/type of products and distance	Euros
	Assessment of temporary storage (if required) (see 5.2)		
	Expected bridging period		Time
	Expected storage costs	Depending on how to be stored, for example due to weather	Euros
	Research into methods for installation in the adoptive structure (re-assembly)	For example, the method of hoisting in during a conversion (repurposing)	
Suitability of product due to age and quality partly correlated with the envisaged residual service life	Research into the year of construction of the donor structure	From the municipal archives or from the owner of the structure	
	Research to find out the year in which the product was installed if this differs from the year of construction	From contract documents or product sheets	
	Alternative: Determination by means of time-related or other distinctive aspects of the product and behaviour over time in the donor structure		

	Establishment of the residual service life of the product	Also use previous assessments of the condition	Attached
Mechanical and other material properties of the product	Research into the mechanical and other material properties by:	The actual study required will depend on the specific application in the adoptive structure	
	Analysis of calculations and drawings still available	From municipal archives or from the owner of the structure	
	Research into the function of the product	Examples of functions of a product are load-bearing (structural), fire-partitioning or part of an outer shell	
	Product research through tests	Examples include X-ray tests, ultrasound tests and load tests	Attached
	Research into quality via quality or performance declarations still available	The minimum statutory retention period for producers is 10 years	
	Standards in force at the time of installation, while constructing the donor structure or during a subsequent conversion	These will provide an impression of the load, load factors and calculation methods	NEN standard
	Establishment of material strength (for example, pressure, tensile, shearing)	Possibly by applying a minimum threshold or a fixed value, depending on the time that has elapsed since the donor structure was built	Value
	Establishment of stiffnesses (modulus of elasticity)	Possibly by applying a minimum threshold or a fixed value, depending on the time that has elapsed since the donor structure was built	Value
	If applicable at the time of application in the adoptive structure:		Value
	Establishment of fire safety properties (fire resistance, fire and smoke classes)	By means of a performance declaration or by testing	Value
	Establishment of the insulation value (Rc value or U value)	By means of a performance declaration or by studying the product	Value
	Establishment of noise index (NEN 5077)	By means of a performance declaration or by testing	Value

Plausibly demonstrating that, upon application of the product, the adoptive structure will be able to meet structural safety requirements	Testing against the public-law construction requirements for application in the adoptive structure	New-build (Eurocode) and conversion (NEN 8700)	
	Research if standards differ from the actual situation (for example transverse force in connection with concrete)	NEN 8702 for concrete, NTA 8713 for steel. Otherwise testing or by expert judgement	Research
	Equivalence in relation to standards differing from the actual situation	Or by overdimensioning	Analysis
	Possibly testing against private law structural requirements, for example deflection		
Plausibly demonstrating that, upon application of the product, the adoptive structure will meet the other technical requirements of the construction regulations (if applicable)	Depending on the place and the function of the product:	Requirements will depend on the use function and type of the adoptive structure (new-build or conversion)	
	Assessment against requirements on strength in case of fire	Or by protective overdimensioning	Research
	Assessment against fire and smoke development requirements	Fire and smoke classes (different for existing structures and new-build structures)	Value
	Assessment against requirements on resistance to fire penetration and fire spread (Dutch wbdbo)	Note: the strength in case of fire must be greater than the wbdbo requirements	Value
	Assessment against sound-proofing requirements		Value
	Assessment against moisture-proofing requirements	For example as part of the external wall or roof	Research
	Assessment against the required insulation value (Rc value or U value)		Value
	Establishment of the structure's ECI value	The ECI value when reusing products is usually lower than when using new products	Value

4.3 Frameworks for quality studies of structural products

4.3.1 General framework

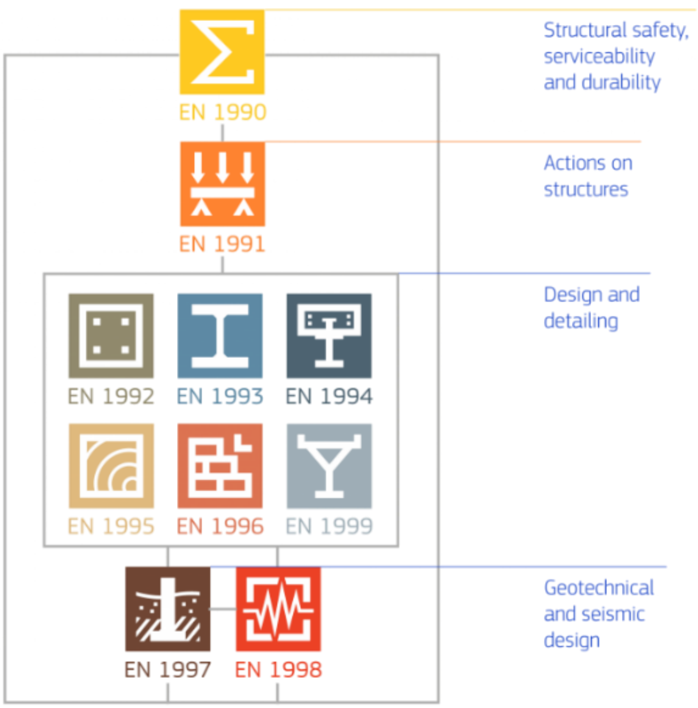
The exact materials that structural products are composed of, or their properties, age and condition, are often unknown. If so, the behaviour of the structure must be tested in order to predict future performance.

Three aspects are important when testing structural products:

- composition and mechanical material properties (see Noordhoek, 2022);
- the load, the load-bearing capacity and the deformation capacity [6];
- the residual service life.

Various tests are needed in order to obtain information on these three aspects.

The basis for these tests can be taken from the Eurocodes. The Eurocodes suite consists of ten European standards for structural design. These standards contain specifications for mechanical material properties. Structures made of different materials (concrete, steel, steel and concrete composite, timber, masonry and aluminium) are treated separately. Each Eurocode consists of several sections that cover specific technical aspects. Figure 7 illustrates the relationships between the Eurocodes.



Source: European Commission 2022

Figure 7 – Relationships between the Eurocodes

[6] How accurately these aspects can be predicted will depend on how well models can predict the structural response and how well they can quantify and explain the uncertainty in the structural prediction, based on the design models (Allaix et al., 2022).

4.3.2 Reuse parameters

The generic quality parameters affecting reuse can be divided into five categories for all structural products:

- general data;
- load-bearing capacity;
- residual service life;
- detachability;
- environmental data.

Table 2 lists the parameters for the four most commonly used structural materials per category. These parameters form the basis for the quality studies for structural products made of these materials (see sections 4.4 - 4.7). For the sake of completeness, the table also deals with non-structural products.

Table 2 – Possible reuse parameters per category

Category	Parameter	Structural products	Non-structural products
General data	Availability of original documents/calculations	X	X
	The material's past is known (maintenance history)	X	X
	Age	X	X
	Current environment (+ during previous lifetime)	X	X
	Load history	X	
	Quantities + planning schedule/availability	X	X
	Fire class	X	X
	Owner	X	X
	Current function of product	X	X
	Dimensions	X	X
	Location	X	X
Load-bearing capacity	**Concrete**		
	Concrete strength class	X	
	Rebar quality	X	
	Modulus of elasticity	X	
	Reinforcement configuration	X	
	Concrete cover	X	X
	Concrete mixture	X	X
	Steel		
	Steel grade	X	
	Tensile strength	X	
	Flow stress	X	
	Yield stress	X	

Category	Parameter	Structural products	Non-structural products
	Notch impact strength	X	X
	Flexural strength (certain applications)	X	
	Chemical composition	X	X
	Timber		
	Dimensional stability/dimensions	X	X
	Type of wood	X	X
	Strength	X	
	Masonry		
	Compressive strength of masonry	X	
	Flexural tensile strength	X	
	Adhesion strength of masonry mortar	X	
	Type of brick; quality	X	X
	Mortar composition and quality	X	X
Residual service life	**All materials**		
	Condition/state	X	X
	Machining	X	X
	Defects	X	X
	Concrete		
	Damage mechanisms (carbonation, chlorides, etc.)	X	X
	Permeability	X	X
	Frost/thaw resistance	X	X
	Environmental class	X	X
	Cover	X	X
	Steel		
	Damage mechanisms (corrosion, etc.)	X	X
	Coating	X	X
	Composition	X	X
	Timber		
	Degradation	X	X
	Imperfections	X	X
	Type of wood	X	X
	Impregnation	X	X
	Masonry		
	Impregnation	X	X
	Permeability	X	X
	Frost/thaw resistance	X	X
	Joint hardness	X	X

Category	Parameter	Structural products	Non-structural products
	Type of brick; quality	X	X
	Mortar composition and quality	X	X
Detachability	**All materials**		
	Type of joint or connection	X	X
	Number of joints or connections	X	X
	Crossings	X	X
	Method of application	X	X
	Form inclusion[7]	X	X
	Accessibility of the connection	X	X
	Location (surroundings)	X	X
	Location in the structure	X	X
	Concrete		
	Composition (prefab/in situ)	X	X
	Steel		
	Type of steel	X	X
	Timber		
	Type of timber (laminated, sawn)	X	X
	Masonry		
	Type of mortar	X	X
	Application (elements or continuous masonry)	X	X
Environmental data	**All materials**		
	Building physics properties (insulation, noise, etc.)	X	X
	Presence of toxic materials (asbestos, PAH, heavy metals such as chromium-6, etc., see 5.1.1)	X	X
	Concrete		
	Environmental class	X	X
	Type of cement	X	X
	Application	X	X
	Steel		
	Presence of coating layer (chromium-6)	X	X
	Timber		
	Layers containing chromium-6	X	X
	Presence of impregnation	X	X
	Masonry		

[7] *In the case of form inclusion, there is a locked object that can only be removed from the surrounding structure by removing one or more other objects*

Category	Parameter		Structural products	Non-structural products
		Coating/impregnation	X	X
		Type of cement	X	X

4.3.3 Studies/Research

Information on the most generic reuse parameters can be obtained by means of:

- file research;
- knowledge of the donor structure;
- visual inspection;
- non-destructive measurements.

Verify the results from file research through on-site examination for parameters such as dimensions, condition and connections.

Destructive testing is often necessary in order to assess the detachability parameters for the type of connection. Data in files is often inadequate and connections are often finished or hidden behind surrounding building parts.

Environmental parameters often require specialised research. Examples are having the presence of asbestos, PAH and heavy metals, such as chromium-6, examined by certified inspectors and researching building physics on site or in a specialist laboratory.

4.4 Concrete quality studies

4.4.1 Reuse parameters

There are several different types of older concrete that have been used in existing structures. Examples are normal concrete, heavyweight concrete, lightweight concrete, fibre-reinforced concrete, dry mixed concrete, self-compacting concrete with light or heavy aggregates or fibres, concrete with an open structure, cellular concrete, foamed concrete, concrete with a volumetric mass of less than 800 kg/m^3 and fireproof concrete (see NEN-EN 206). The first uses of concrete (including in the Pantheon in Rome) date back as far as 118 and 125 AD.

Concrete tends to be well suited for reuse because it has a very long service life, provided it is properly designed, processed and maintained.

Whether concrete can be reused will depend on a number of factors. The production method (prefabricated or cast in place) and, in connection with that, the detachability of the element in particular are decisive factors. Also important are the area of application (environmental class) and related exposure to different environmental conditions (varying conditions of drying and wetting, chloride environment, carbonation, chemical attack, alkali-aggregate reactions, etc.).

The amount of reinforcement is often decisive for structural safety. Different standards and requirements were applied in this respect in the past. This is also true for the minimum cover requirement.

Figure 8 shows the reuse parameters for concrete products.

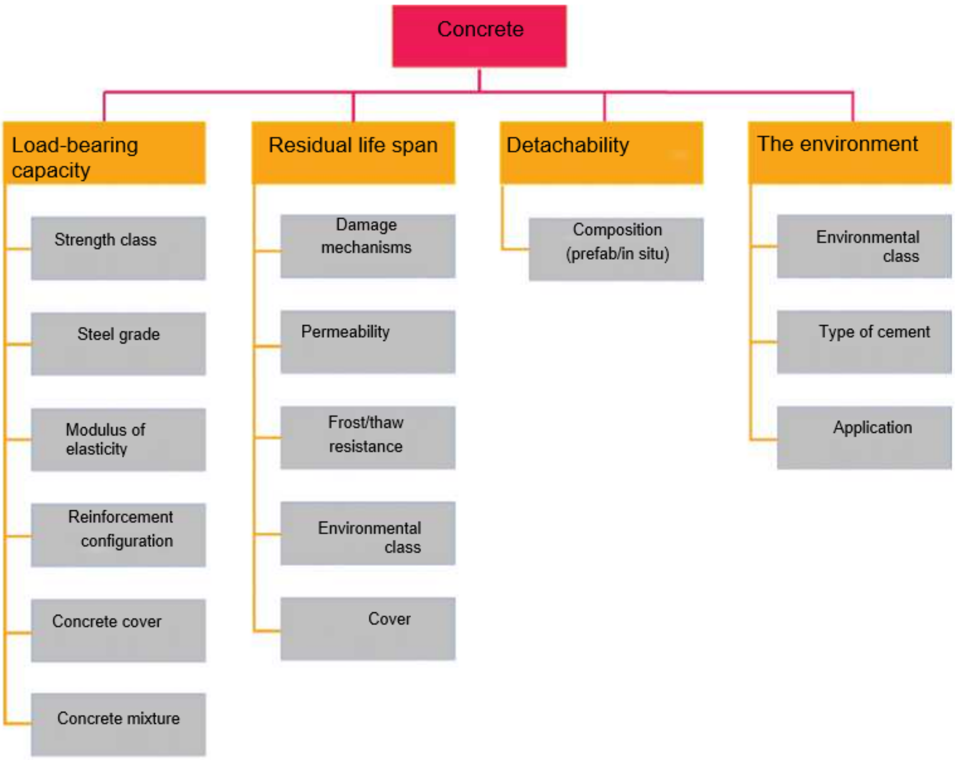


Figure 8 – Concrete reuse parameters

4.4.2 Studies/Research

Many of the reuse parameters for load-bearing capacity and detachability can be retrieved through file research. Of course, this requires the original design documents and calculations to be available.

In practice, information from files is not always sufficient. In such cases, an analysis based on year of construction, method of construction and type of product can give a first impression of the reuse potential because there is a great deal of knowledge about the structural properties of old concrete. See, for example, the NEN 8700 series and the Dutch guidelines on the assessment of engineering structures (Richtlijnen Beoordeling Kunstwerken - Rijkswaterstaat, 2013).

A final assessment of structural safety often requires material testing in the field and the laboratory.

As regards the residual service life of concrete, a visual inspection on site can already give an impression of its condition and any forms of damage that might affect this. Depending on the type of damage, this inspection can be followed by targeted research for chloride, carbonation, cover and possibly the alkali-silica reaction (ASR). This requires a combination of non-destructive testing (by using a concrete radar and/or a ferroscan, for example) and destructive testing, supplemented by laboratory testing.

Often no or little information is available on the original composition (cement, aggregate, fibres, coating) of a concrete product and only the original supplier will have this information. In such cases, the properties of a concrete product (strength class, reinforcement/no reinforcement, type of reinforcement) and the degree of contamination can only be largely found out by means of physical and chemical laboratory analyses.

4.5 Steel quality studies

4.5.1 Reuse parameters

Steel is an alloy of iron and carbon. It contains less than 2% carbon and 1% manganese, along with small amounts of other chemical elements.

The shape of a steel product determines its structural properties. The sections and cross-sections of steel products come in various shapes (hot-rolled, welded and composite, cold-rolled).

Just like concrete, steel has a high reuse potential because it generally has a long service life and lends itself well to being detached. Bolted connections without rivets or welding in particular lend themselves well to reuse. Whether steel is actually reusable will also depend on the steel grade. Environmental aspects complicating steel reuse include the presence of heavy metals such as chromium-6. Corrosion and fatigue are the main contributors affecting the residual service life of a steel product.

Figure 9 shows the reuse parameters for steel products.

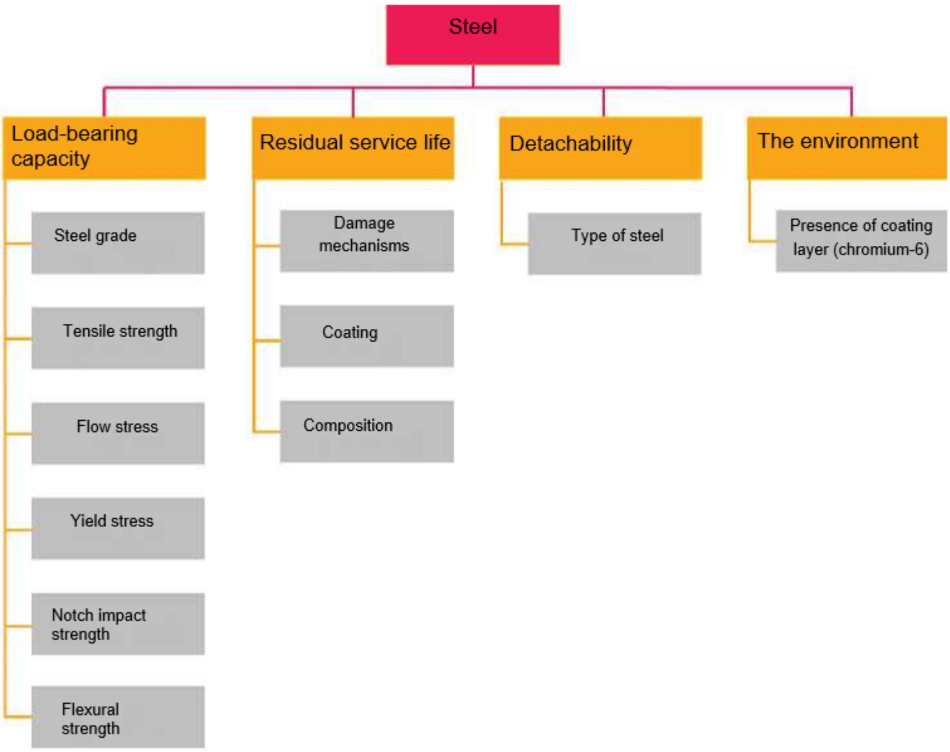


Figure 9 – Steel reuse parameters

4.5.2 Studies/Research

Conduct quality studies on steel for reuse in accordance with NTA 8713 Hergebruik van constructiestaal (Reuse of structural steelwork).

4.6 Masonry quality studies

4.6.1 Reuse parameters

Masonry is generally very suitable for reuse because the bricks and blocks used for this tend to have standard sizes.

An important factor affecting the reuse of masonry is how the bricks and blocks have been fixed. The cement mortars used today are more difficult to separate than lime mortars (Kanters, 2018). This makes the reuse of masonry more difficult. In the future, the reuse of masonry will become easier thanks to the increased use of "dry-stacking methods".

Requirements for masonry made of brick, sand-lime brick, prefabricated building blocks and bricks made of special concrete, aerated concrete and natural stone can be found in NEN-EN 1996-2.

Figure 10 shows the reuse parameters for masonry.

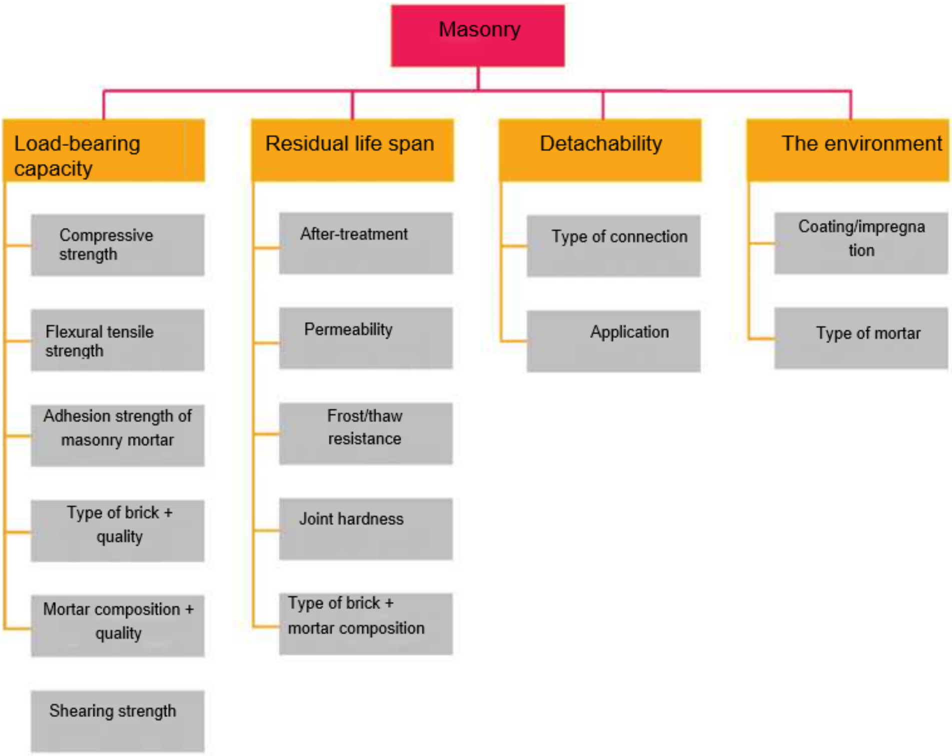


Figure 10 – Masonry reuse parameters

4.6.2 Studies/Research

Information on masonry reuse parameters can be obtained in several ways.

File research is the easiest and lowest cost way to obtain information. It consists of checking whether original construction calculations, contract documents or specification sheets are still available, for example. However, in practice, these are often not available.

If file research does not yield results, a visual inspection and non-destructive measuring can provide information. The year of construction, the application and how the masonry looks often say a lot about the type of brick and the mortar composition. This can give an indicative idea of the properties. At the start of the process, this is often enough to be able to choose between reuse and upcycling.

Reuse requires mapping parameters better and with more certainty. The following and other tests can be used for this:

- joint hardness measurements with a pendulum hammer;
- lever tests to determine the cohesion of the masonry;
- compressive tests to assess the compressive strength of the bricks;
- core drilling supplemented by laboratory testing to identify the physical properties;
- samples of the masonry mortar combined with chemical laboratory analyses;
- building physics tests to assess permeability and frost and thaw resistance.

These tests will provide a good idea of the properties of the masonry wall and its potential for reuse. However, this often based on random samples. To map the properties of an entire exterior wall, you can also take whole sections from it and test them in a laboratory. It is also advisable to assess non-visible parts visually after dismantling, and to supplement this with measurements and further examination where necessary.

4.7 Timber quality studies

4.7.1 Reuse parameters

Older timber structures are ideal for reuse. These structures tend to be made using simple construction techniques and standard dimensions. Specific types of timber are sawn timber, glued laminated timber, LVL (laminated veneer lumber), plywood, OSB, chipboard and fibreboard (hard, medium, MDF and soft) (see NEN-EN 1995).

The type of connection is an important factor for the reuse of timber. Bolted connections or connections with sheet metal connectors are easy to dismantle, making them ideal for reuse.

Structural timber can be reused if it meets the general requirements set out in NEN-EN 14081-1 and NEN-EN 14080 for structural timber and laminated timber, respectively (Whittaker et al., 2021).

Timber can only be reused as a structural material if its mechanical properties are known and safety can be guaranteed. Relevant factors are the natural ageing phenomena of wood, the duration of loading (static fatigue), local mechanical damage and biological degradation (Niu et al., 2021). There are many different methods for detecting mechanical and biological damage (Dietsch & Köhler, 2010).

Figure 11 shows the reuse parameters for timber.

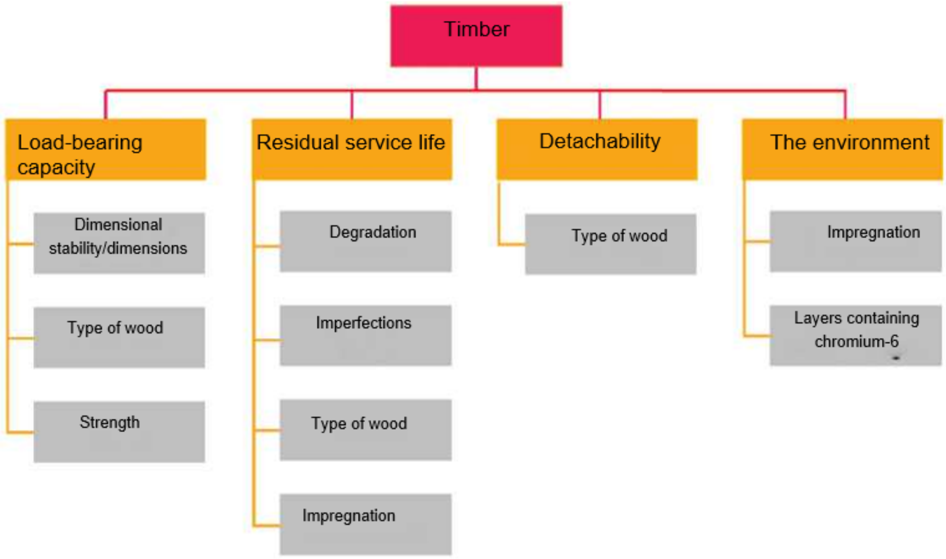


Figure 11 – Timber reuse parameters

The use of construction timber originating from construction and demolition waste is difficult at present. This is because construction timber[8] is graded by strength according to European and national grading standards. However, there is no specific assessment guideline for the reuse of construction timber or for construction and demolition timber. Even NEN EN 14081-1 specifies that construction timber already assessed in the past is not allowed to be reclassified as the same or different grades unless special dispensation is granted. Moreover, the existing grading standard sets limits on the cross section (e.g. NEN-EN 14081-1). For construction timber originating from construction and demolition waste to be reused, it sometimes needs to be machined (e.g. planed). This affects its cross section, as a result of which the limit for the cross section set out in existing standards may not be complied with (Niu et al., 2021).

4.7.2 Studies/Research

File research tends to yield little information on construction timber. Files often contain limited information on its properties.

A visual inspection is a good first step when assessing the quality of construction timber This gives an initial impression of the state of the timber and any defects. You might use an awl to find rotten spots and other irregularities. A visual inspection often makes it possible to indicate the type of wood/timber too. Based on this, you can then provide an indication of the strength grade and possible applications. This is often sufficient at the start of the reuse process.

In order for donor timber to actually be used, its properties will need to be determined to a higher level of certainty. The following and other tests can be used for this:

- microscopic assessments of timber samples;
- determination of any deterioration using a pilodyn;
- determination of the density profile using a penetration meter;
- test to assess the humidity of the timber.

Most data is obtained by studying samples from the donor timber. Based on these, the type of timber, the strength grade and the presence of intrusions can be determined. It is also possible to subject the timber or parts of it to a failure test in order to determine the structural properties with great

[8] It should be noted that this also applies to wood for processing into composite timber products.

certainty. However, this is only possible if there is a lot of construction timber available as you will "sacrifice" some of the timber for the testing.

5 Implementation

If the matchmaking (Chapter 3) results in a product being purchased/sold, the implementation phase then follows. In this phase, dismantling takes place (if no previous dismantling has taken place), the product is transported and possibly repaired and/or stored, and eventually applied in the adoptive structure.

This chapter describes the process starting from procurement/sales (see figure 12). Some concluding quality studies are sometimes carried out during this phase (see Chapter 4), but the main thing here is to assure the quality on the basis of which the pull side decided to purchase.

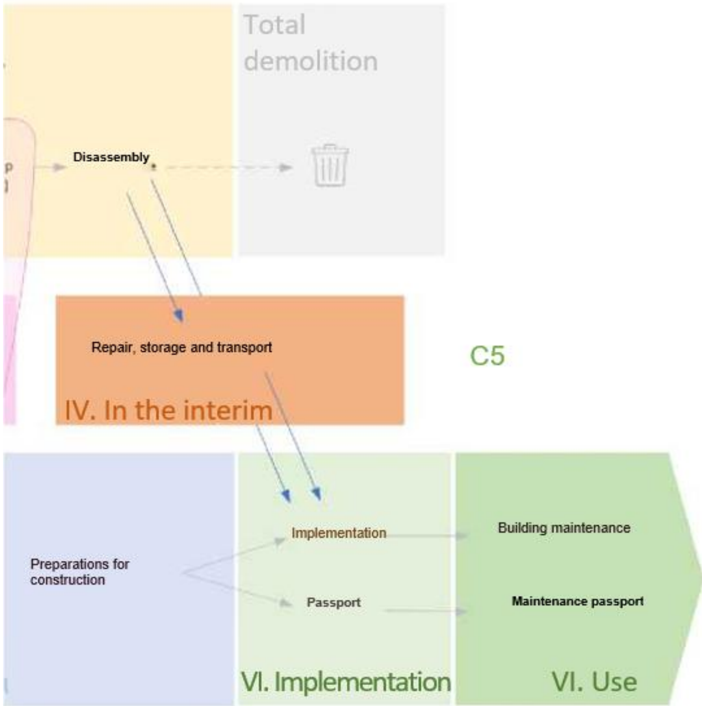


Figure 12 – The position of Chapter 5 in the reuse pathway

5.1 Demolition/dismantling

5.1.1 Stocktaking of substances

Before a demolition company demolishes/dismantles a structure, it will take stock of the substances present as a standard procedure. As a demolition company that is a party to a reuse project, you can include the information already collected for the purchase/sale (see 2.4.2 and 2.5).

When taking stock of substances, you record the following details to an extensive level:

- raw materials, materials and products for reuse released from the structure and any contaminations affecting them;
- released waste substances that are to be separated (see below).

Keep the results of the stocktaking of substances in the project file.

Waste substances to be separated

Based on the Dutch 2012 Building Decree Regulation (Regeling Bouwbesluit 2012; Overheid.nl, 2023a), the following categories of waste must be properly separated:

a) any substances classified as hazardous waste in the European List of Waste Regulation (Overheid.nl, 2023b), if not already on this list. Examples are asbestos, heavy metals (including chromium-6), PCB, mineral insulation from before 1996 and components of radioactive plants);
b) tar-containing roofing materials, with or without roof boarding (PAH);
c) tar-containing asphalt (PAH);
d) bituminous roofing materials, with or without roof boarding;
e) non-tar-containing asphalt;
f) sheet glass, with or without frame;
g) plaster blocks and plasterboard material;
h) roof gravel;
i) light fixtures;
j) gas discharge lamps.

Recording
Record the results of the stocktaking of substances as follows:

- Make a list of products released broken down by scale levels (raw material, material, element, construction product).
- Record the following for every product:
    - size/quantity;
    - quality;
    - location in the structure;
    - how it is fixed to the structure;
    - score on the R ladder.
    - dismantling method;
- Record both the EUAL code and the NL/SfB code.

5.1.2 Project work plan and dismantling plan

Based on the stocktaking of substances and the agreements on products to be reused, you prepare a project work plan including a dismantling plan for the demolition phase.

Include the following topics in the **project work plan** as a minimum requirement:

- products to be dismantled for use in a subsequent cycle, based on the R ladder;
- parts to be demolished traditionally and the level of recycling (upcycling or downcycling), if applicable;
- other activities;
- planning of the demolition work and techniques to be used;
- nuisance caused by the work;
- how the demolition requirements of the 2012 Dutch Building Decree (Overheid.nl, 2023a) and any supplementary municipal conditions will be met;
- dismantling plan (see below).

Include the following in the **dismantling plan** as a minimum requirement:

- work instructions and/or competence requirements for personnel;
- a list of raw materials, materials, elements and construction products released and the nature and scope of any contamination (see 5.1.1);
- dismantling activities to be carried out in order to harvest products for reuse and the method of packaging, transportation and temporary storage (see 5.2);
- quality aspects that the product must meet (possibly with a reference to specific product sheets), including internal rejection criteria, external acceptance criteria and how to assure those criteria;
- how and by whom the product will be checked;
- destination for products for reuse (storage, adoptive structure or otherwise);
- how it will be checked that the products for reuse are properly removed from the site;
- materials released that will not be reused, including the separation method and the disposal destination, classified into upcycling and downcycling;
- a list of released waste substances to be separated (see 5.1.1) with expected quantities;
- registration requirements.

5.1.3 Demolition

During the demolition phase, you use the project work plan (5.1.2) to demolish/dismantle the structure, separate products and package them, and remediate or make safe any waste substances that are not structural products.

Any materials released that have to be classified as waste shall be handed over or transport to an authorised recipient, pursuant to the Dutch Environmental Management Act (Wet milieubeheer; Overheid.nl, 2023c). Materials may also be separated at a different location if this cannot be done efficiently at the demolition site. A prerequisite for this is that the competent authority has to agree to this in writing, pursuant to the 2012 Dutch Building Decree.

Before removing the products from the site, check that the products to be reused meet the buyer's quality and acceptance criteria.

Any deviations from the project work plan must be recorded. Adjust the project work plan where necessary and contact the buyer of the product to be reused.

5.1.4 Account of substances and materials/handover

On completion of demolition/dismantling, you prepare an account of the substances and materials based on the stocktaking of substances (5.1.1). The dismantling client should be able to verify this account of substances and materials, from the time of dismantling up until the time of storage or application in the adoptive structure.

The following information must be recorded in the account of substances and materials as a minimum requirement:

- old location;
- new location (if known) or storage location;
- manufacturer (if known);
- quality;
- dismantling date;
- dismantling contractor or party carrying out the dismantling;
- mass (kg);
- dimensions;
- type of product;

- material family;
- material;
- type;
- function test results;
- reuse potential (on the R ladder).

5.2 Transport and storage

Ideally, a product for reuse will immediately be applied in the adoptive structure. In such cases, it is sufficient to check (usually by means of a visual inspection) that the product meets the buyer's quality and acceptance criteria.

If the planning schedules for the push and pull sides do not match, the product will need to be stored temporarily – in the yard of the demolition company that sold the product, for instance. Store the product in such a way that its quality does not deteriorate.

5.3 Completion and commissioning

Clients on the pull side purchasing multiple products for reuse are advised to prepare an adoption list. Such a list will state all products for reuse, the agreements and responsibilities (relating to logistics, for example) and the planning schedule. Use the adoption list while preparing and implementing the construction activities, monitor that everything goes according to plan and make adjustments where necessary.

Once a product has been installed in the adoptive building, it is good to facilitate its reuse in a subsequent cycle. You do so by recording data on the product in question in a passport for the construction sector (see Platform CB"23, 2022), updating that data if changes occur and maintaining the product well. A product displaying many signs of wear will go down in value and will be less likely to be reused.

Upon completion, record the following details about the product used as a minimum, preferably in a passport for the construction sector:

- new location;
- assembly contractor;
- connected products;
- residual service life;
- application;
- supplementary test results;
- materials that make up the product;
- mass (kg);
- dimensions.

6 Lessons learned from projects

Quality assessment and assurance in reuse projects is already happening in practice. This chapter outlines how this is being done using example projects provided by the working group members who wrote this guide. The example projects serve as sources of inspiration and contain both lessons to be learned and success factors.

6.1 Buildings sector

Improvement project #1	
Project name	Reuse of hollowcore slab flooring in an existing design
Reused material	Structural material, concrete, hollowcore slab flooring
What went wrong?	In this project, hollowcore slab elements that could be fitted into the design were found. So, in principle, there was a match and the elements could be examined to demonstrate that they were suitable for use, but since the reuse of elements was not considered until late in the process, the client was reluctant to apply them. In the end, the client decided that new elements should be used.
How was this resolved or how could it have been resolved?	If the client had been informed about the reuse possibilities to a greater level in advance, they would probably have viewed reuse in a more positive way and would probably have been more inclined to use reused elements in the building.
Lessons learned or areas for attention for similar projects	Involve the client in the reuse process from the beginning.

Improvement project #2	
Reused material	Gym floor
What went wrong?	A beautiful wooden floor was released from an old gymnasium, but storing the floor in a conditioned room for the time required (two years) was too costly. The floor was stored in the donor building first, followed by storage in the building to be renovated, in which the floor would be applied. When the building was demolished to the extent that only its shell remained during the renovation, the floor was placed on battens for the last six months (ventilation kept the floor dry) and covered by tarpaulins to protect it against the weather. The floor survived because the right action was taken, although this was far from certain at the start of the storage process.

How was this resolved or how could it have been resolved?	The client could have organised storage space elsewhere in advance. This would have involved transportation and storage costs.
Lessons learned or areas for attention for similar projects	Organise storage as soon as it is clear that material will be released from a donor building.

Improvement project #3	
Reused material	Ceiling tiles
Where in the process did things go wrong?	The client made clear agreements when preparing for the process, but the subcontractor failed to comply with those agreements. Moreover, more square metres then necessary were ordered during the preparatory stage.
What went wrong?	It was agreed with the subcontractor that standard modular ceiling tiles should be treated for reuse. A different type of hard mineral ceiling tiles were returned to the site (mismatch). The input figures on which the calculation was based were too high (the number of square metres delivered was approximately 20% more than required). This was a waste of energy, labour and transport/CO_2 emissions. In this case, things turned out well in the end because many tiles were not suitable for reuse and the wrong tiles had been delivered. The fulfilment by the contractor of the guarantee obligations was slow to materialise. The subcontractor was given the opportunity to remedy their mistake, but this took a very long time. An estimate was made of how many square meters of ceiling tiles were unusable. A reservation was made for new ceiling tiles in order to manage the risk that insufficient tiles might be available during the work, resulting in the work coming to a standstill. Planning problems were managed by reserving new ceiling tiles in good time to replace the unusable ones. The subcontractor initially failed to adequately make use of the opportunity to rectify its mistake. The employee who was sent to the site arrived there totally unprepared and left again without having resolved anything. A second visit was made to the site by other employees and they helped to resolve the problem. The damaged tiles were not reimbursed to the client. Some 200 m^2 of the 1300 $m^2$of tiles in total, i.e. 15%, were found to be unsuitable for reuse. This was due to damage, breakage and tiles sticking together, making them impossible to reuse.

How was this resolved or how could it have been resolved?	The cardboard boxes containing the reused tiles looked undamaged and new. The boxes were not opened on delivery. When the boxes containing the ceiling tiles to be reused were eventually opened, it was found that the tiles were largely unusable. Stocktaking showed this to be approx. 15%. Checking the quality of deliveries immediately enables adequate intervention if this is needed.
Lessons learned or areas for attention for similar projects	Carry out sample checks of the contents of the delivery and do not only assess whether the packaging in which the products are delivered is undamaged.

Improvement project #4	
Reused material	Timber slatted ceiling
Where in the process did things go wrong?	The project was expanded during the implementation phase, requiring more square metres of ceiling.
What went wrong?	The client ordered the right number of square metres of ceiling, but because battens with recesses were delivered, that number was insufficient. Cutting losses were also higher than anticipated. The donor building contained additional ceiling material, but this would not be released until the subsequent dismantling phase. Sufficient ceiling material was still available, but this was in hard-to-reach places in the part of the donor building that was being demolished. The client's contractor decided to take a crew to the building in the weekend and remove the necessary square metres of ceiling elements from these places. The ceiling elements were taken down and carried away by manual labour. This required a considerable personal effort, which was well beyond what the client could expect from the contractor.
How was this resolved or how could it have been resolved?	The efforts made by the client's contractor ensured that sufficient ceiling elements were available to complete the project satisfactorily. This could have been avoided by building according to plan or by making use of personnel with experience in estimating volumes in order to minimise the risk of shortages. Because it was difficult to estimate how much was actually required, an option would also have been to supply more material as spare material. This spare material could then have been kept aside and returned to the supplier if it was found not to be needed.
Lessons learned or areas for	Gain experience of estimating the required quantities of material.

attention for similar projects	Hedge risks by delivering or ordering more square metres than estimated, with a guarantee that the materials delivered in excess will be taken back and will not end up in a skip as waste after all.

Improvement project #5	
Reused material	Air handling units (AHUs)
Where in the process did things go wrong?	In the preparatory phase, the client made some assumptions based on information available at the time of the transfer of the building.
What went wrong?	The AHUs were preserved for circularity purposes. While dismantling was taking place, calculations were carried out showing that, given the energy consumption and environmental considerations, replacing the units would be the better option in the long run, even if all investments for the purchase and production, delivery and installation were taken into account. Based on the calculation, it was eventually decided to replace certain existing units with new ones. This led to additional work for the client. Some demolition work had to be carried out during the disassembly phase.
How was this resolved or how could it have been resolved?	The calculations should have been done ahead of the project, so that demolition and removal in the disassembly phase and additional work could have been avoided.
Lessons learned or areas for attention for similar projects	Where necessary, check any assumptions made through research and calculations prior to formulating an order.

Improvement project #6	
Reused material	HPL Volkern panels (Trespa® or comparable) as rear cladding
What went wrong?	The panels met criteria of the architect's request in terms of dimensions, thickness and colour when the project was put out to tender. However, the building contractor was not amenable.
How was this resolved or how could it have been resolved?	This could have been resolved by hiring a builder who is compliant with the use of used materials (co-makership).
Lessons learned or areas for attention for similar projects	Assemble in advance a construction team consisting of people with the same intrinsic motivation to reuse used materials. The client/architect/design team should take control and keep that control if someone within the design team turns out to be causing a problem.

Improvement project #7	
Reused material	Kitchen
What went wrong?	The client had designated a beautiful stainless steel kitchen for reuse. In spite of stickers having been applied to the kitchen and despite making a reservation with the contractor, the kitchen was not retained. When the building was dismantled (demolished), the kitchen was unexpectedly found to have already been removed. The contractor then investigated the matter and identified the person who had stolen the kitchen, ordering them to return it. The person who had taken it away did return it, but it was found to have been completely compressed. It had been taken as a way to earn some extra money by selling it as scrap steel. As a result, the client was forced to order a Bruynzeel kitchen.
How was this resolved or how could it have been resolved?	By supervising more valuable and other materials designated for reuse.
Lessons learned or areas for attention for similar projects	Organise supervision and (random) monitoring of workers/subcontractors/transportation leaving the construction site in order to ensure that nothing is stolen.

Improvement projects from demolition – general	
Reused material	Products with which things can go wrong are: • roof beams (wrong dimensions); • roof boarding (too dry); • toilets, washbasins, kitchen units, taps, and door and window frames.
What went wrong?	A reuse project can go wrong because: • the demolition company is involved too late on (and everything has been prepared); • the request to tender is put out to the market late; • the period between the outcome of the tender and the start of the work is too short; • the products for reuse are not installed as expected; • the condition of the products is not assessed properly; • products are installed incorrectly. Sometimes, stocktaking for demolition for reuse projects is not carried out properly. This can be because: • products are categorised as suitable for reuse when they are not; • the locations that products should go to are not indicated; • the quantities or materials are incorrect.
Lessons learned or areas for attention for similar projects	General lessons are: • Involve the demolition company at an early stage of the process. • Start the tender process in good time. • Make sure there is enough time between the outcome of the tender process and the start of the work. • Ensure stocktaking is clear and practical. • Assess feasibility in advance. • Make the cost and revenue transparent.

Improvement project and successful project #1	
Project name	Circulaire biobased gemeentewerf in Nieuwkoop (Circular bio-based municipal yard in Nieuwkoop)
Reused material	• 50 m^2 of rough, slightly rusted corrugated sheets; • 110 m^2 of façade timber consisting of thermally modified sawn roof boarding from a pavilion at the Eindhoven University of Technology; • 45 m^2 of hardwood façade timber, originally interior doors from a demolition project, sawn into pieces; • 480 m^2 of façade timber as residual waste from the Hollands Peppelhout* production process;

	• 650 m^2 of prison steel mesh from above an outdoor space at the Zeist juvenile detention centre, to be used for vegetation; • 1 steel station staircase; • 110 m^2*of surplus slabs; • approx. 1300 m^2 of paving; • approx. 300 m^2 of grass concrete pavers; • approx. 400 m^2 of kerbstones; • approx. 56 road humps. The following items were also scouted for and found, but were not reused: • 100 m^2 of modular ceiling; • 550 m^2 of ceiling finish materials; • 25 m^2 of modular wall; • 60 m2 of decking planks. * = not 100% reuse because this was a surplus of new products
What were the success factors?	Everything scouted for was found by searching marketplaces and Repurpose's supply network. The most favourable offer found cost half the reserved procurement budget (based on purchasing new material). This resulted in plenty of financial leeway for achieving the necessary customisation (in matchmaking, changes to the design and changes to materials at the construction site). The client and almost all the contractors wanted to work with bio-based and/or reused construction products. This allowed the team to come up with good solutions together, even where they were confronted with unexpected acute problems or challenges. The municipality itself could temporarily store materials purchased early on at its former municipal yard. Some providers also kept materials in their storage facilities until they were needed at the construction site.
What went differently than expected? **How was this resolved or how could it have been resolved?**	Some offers found did not meet customer requirements. In the end, it was decided not to reuse these but to purchase and use new (and mainly also bio-based) material. The paving materials found were not purchased immediately. The reason for this was that they had been scouted for too early in the process: the site layout design was not yet sufficiently detailed to enable the purchase of the right quantities. Eventually, after quite some time, the paving contractor purchased reused material and installed it. The mesh found for vegetation against the exterior wall turned out to be heavier than expected and the nets did not all have the same dimensions, even though this had been indicated to be the case by the seller. This forced the main contractor to come up with a new solution for fastening them in place and on site the contractor's personnel had to work out how to install mesh panels of varying sizes. The main contractor successfully resolved these challenges in good time.

Lessons learned or areas for attention for similar projects	Follow the advice in this guide when scouting for materials. The point in time at which scouting is wise will depend on the project and product in question. Carrying out several rounds of scouting is advised. Working with the seller, determine what kind of material will be delivered in as much detail as possible so that this can be referred to if something different is delivered.

Successful project #1	
Reused material	Old floorboards as interior wall panelling
Lessons learned or areas for attention for similar projects	Make sure all stakeholders involved fully support the application of used materials. This means that reuse projects can be a real success!

Successful project #2	
Project name	Aeres Almere (Circular Award Public 2022)
Reused material	Non-structural: fittings and fixtures, cladding of walls, locks, ceilings, floor covering; structural: reused concrete/gravel, cement
What were the success factors?	A guiding request for proposals was made during the design process, accompanied by a round of meetings with contractors. The budget was disclosed in advance. An additional matrix of assessment ratings was also prepared, allowing for an additional score for circularity to be included.
Lessons learned or areas for attention for similar projects	Organise a round of meetings in advance and select contractors with experience with and/or ambitions in the field of circularity. Provide clarity on the financial framework in advance and indicate the score and target the client has in mind. Guide the design team from the outset with the aim of increasing ambition from phase to phase. Apply this to the implementation too by selecting the right parties.

Successful demolition projects – general	
Project name	Aeres Almere (Circular Award Public 2022)

Reused material	Products for which reuse is often successful are: • roof boarding; • roof beams; • roof tiles; • door/window frames; • central heating boilers; • doors; • kitchen units.
What were the success factors?	General success factors are: • involving the demolition company in good time (pre-selection during the design stage); • a client willing to look at opportunities following the tender procedure; • honest and open collaboration within a construction team.
Lessons learned or areas for attention for similar projects	• Involve the demolition company in good time and work together. • Be honest and open within a construction team instead of competing with each other.

6.2 The civil and hydraulic engineering sector

Improvement project #1	
Reused material	Catenary mast
What went wrong?	During the dismantling of a project area, it was found that some of the catenary masts released were in good condition. The parties involved wanted to reuse them for another project. Although all the parties involved shared the same motivation and energy, reuse did not take place because too little time was available between the point of release and the time of placement.
Lessons learned or areas for attention for similar projects	Ensure an ample planning schedule. Carry out inspections at the donor site.

Successful project #1	
Reused material	Concrete flyover beams
What were the success factors?	The client was directly involved in the project.

	Because the project was carried out through a consortium, a great deal of knowledge was available. A grant was available, leading to the various parties being more motivated.
Lessons learned or areas for attention for similar projects	Form a close team. Involve the client from the beginning.

Successful project #2	
Project name	Programma Hoogfrequent Spoorvervoer opstelterrein Westhaven
Reused material	Foundation blocks for catenary masts in railway infrastructure (concrete, structural)
What were the success factors?	The blocks were released from a project in Rotterdam where they had been in use for approximately 20% of their total service life. The blocks were in good condition. The blocks were traded internally, making the financial settlement easier. The inspection was fairly comprehensively handled in consultation with the client. This probably contributed to all parties supporting this initiative.
Lessons learned or areas for attention for similar projects	Involve stakeholders. Be transparent. Be open and honest about costs.

Successful project #3	
Project name	Theemswegtracé
Reused material	Reused catenary mast as a foundation for a noise barrier
What were the success factors?	A change in railway infrastructure freed up about 100 catenary masts. The masts were very specific and were no longer being used in infrastructure. A new application for them was sought, working with VolkerWessels' noise barrier builder. And one was found: the masts were used as foundations for noise barriers. This project involved communication regarding who would do what and separating the transportation and inspection elements from the standard projects.
Lessons learned or areas for attention for similar projects	Involve stakeholders. Be transparent. Be open and honest about costs.

	Deviate from the regular process if necessary.

Successful project #4	
Reused material	Ballast/crushed stone
What were the success factors?	Ballast/crushed stone is often released from railway projects. Several companies were involved in excavating, transporting and sieving the material, after which each of these companies could use a portion for its own operations.
Lessons learned or areas for attention for similar projects	Work together. Be transparent.

7 Recommendations

7.1 Continue to further develop the topics covered in this guide

This guidance provides a general framework for quality assessment and assurance for reuse (see 1.2). The information will need to be expanded on for specific product groups, possibly leading to NTAs.

Quality studies for the four most commonly used structural materials (concrete, steel, masonry and timber) are described in this guide. However, further elaboration is still needed for those products as well. An NTA has recently been drafted for structural steel; NTAs for concrete, masonry and timber still need to be prepared.

Further standardisation is recommended, particularly for the quality assessment of timber (see 4.7.1). The European and national grading standards complicate the reuse of construction timber originating from construction and demolition waste and there is no specific assessment guideline for its reuse.

Recommendations for the most commonly used structural materials will also have to be made for product subgroups – for different types of concrete, for instance.

When further developing this guide, integrating new findings from the NEN working group on structural elements (working group 351001) is advised.

7.2 Promote the reuse market

Because the reuse market is still small, successful reuse currently still requires active matchmaking (see 1.3). Because of this, the quality assessment and assurance of products from reuse still takes place within the context of matchmaking.

To achieve circular construction objectives, the government will need to promote the reuse market. This will require pressure and coercion. Including mandatory percentages of products from reuse in the Dutch Building Decree would be one method.

As the reuse market matures, the quality assessment and assurance process will also need to be reviewed. The soft side of matchmaking (see Chapter 3) will then become less important and the technical, hard side of quality studies (see Chapter 4) will become more important.

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