

Resource assessment for the reuse of load-bearing reinforced concrete components



Version 1.1 – December 2022

Authors: Julie Devènes, Maléna Bastien-Masse, Corentin Fivet



EPFL ENAC IA SXL
Smart Living Lab - HBL
Passage du Cardinal 13b
CH – 1700 Fribourg

Structural Xploration Lab
+41 21 696 72 32
corentin.fivet@epfl.ch
<https://sxl.epfl.ch>

Funding

This work was funded by Immobilien Basel-Stadt (IBS).

To cite this report

Devènes J., Bastien-Masse M., Fivet C. (2022), “Resource assessment for the reuse of load-bearing reinforced concrete components”, Ecole Polytechnique Fédérale de Lausanne (EPFL) and Immobilien Basel-Stadt (IBS), Fribourg and Basel. DOI: 10.5281/zenodo.7457909

First page figure

Reuse of cast-in-place concrete parts for the Udden project in Sweden, 1997.

Image published in: Eklund, M., Dahlgren, S., Dagersten, A., & Sundbaum, G. (2003). The conditions and constraints for using reused materials in building projects. *Deconstruction and Materials Reuse*, 287, 248–259.

Table of content

Summary	4
1 Introduction	5
1.1 Context	5
1.2 Objectives.....	5
1.3 Scope	5
2 Reusability assessment	7
2.1 Preamble.....	7
2.2 Reinforced concrete damage types.....	7
2.2.1 Generalities.....	7
2.2.2 Corrosion of steel reinforcement	7
2.2.3 Cracking.....	8
2.2.4 Alkali-silica reaction.....	8
2.2.5 Water damages.....	9
2.2.6 Concrete spalling or chipping	9
2.3 Damage class	9
2.4 Use class.....	10
2.5 Intervention class	11
2.6 Reusability grade.....	11
3 Resource assessment protocol	15
3.1 Preamble.....	15
3.2 Review of existing data.....	15
3.3 Classification of components	16
3.4 On-site visits and visual inspection	16
3.5 Damage assessment	16
3.6 Investigations on geometry	16
3.7 Investigations on materials	17
3.7.1 Destructive investigations.....	17
3.7.2 Non-destructive investigations.....	17
3.8 Other assessments of components	18
3.8.1 Aesthetics	18
3.8.2 Accessibility	18
3.8.3 Cross-section resistance	19
3.8.4 Volume significance	19
3.8.5 Environmental impacts	19
4 Reporting	20
4.1 Preamble.....	20
4.2 Resource assessment reporting	20
4.3 Summary table.....	21
4.3.1 Discarded components	21
4.3.2 Selected components.....	21
4.4 Components factsheets.....	21

5	Conclusion.....	22
6	References.....	23
	Annex 1 – Checklist.....	25
	Annex 2 – Factsheet templates.....	26

Summary

Today, many reinforced concrete structure, most of the time with no or small structural disturbances, are demolished for socio-economic reasons. When the preservation of an existing building is not possible, reusing the structural component in a new project is a strategy that allows the diminution of the detrimental environment impacts of deconstruction and new construction. The components of the obsolete building are carefully dismantled without being crushed. They are cleaned, possibly repaired or trimmed and reused while maintaining as much as possible their pre-existing geometry and properties. Adopting this alternative strategy implies changes in the design processes of the demolition and new construction projects. As a starting point, the obsolete existing structure must be inventoried and assessed to define the mechanical and geometrical properties as well as the durability of its reinforced concrete components and to evaluate their reusability. The present document describes a reusability assessment method and a resource assessment protocol for a soon-to-be deconstructed RC structure.

To help the designers evaluate the different reuse options for a component, a reusability assessment tool is first presented. It is based on the pre-existing damages of the component, its future use and the intervention required to rehabilitate the components. The damage assessment is conducted before the deconstruction of the donor building. The use class – expressing the structural demand for the component – and the intervention class – describing maintenance and modifications on the component – depend on the design of the receiver building. Once the damage, use and intervention of a component have been classified, the reusability grade is obtained, expressing recommendation for the reuse and the related monitoring in the receiver structure. This reusability assessment tool is intended to reduce the subjectivity of the assessment of reuse potential of RC components.

This report then describes the steps to carry out the complete resource assessment of reinforced concrete structures and their components. The resource assessment collects all information needed to evaluate and plan the future reuse of the components: classification and quantification of the components, grading of their pre-existing damages, investigations on their geometrical and material properties and evaluation of their qualities (aesthetics, accessibility, resistance, environmental impact). This systematic methodology aims at reducing the subjectivity of such an assessment.

The methods and protocols described herein allow planning the deconstruction of an obsolete RC structure using methods that will subsequently facilitate the reuse of the components with the most potential. They also give the information for preliminary designs of a receiver structure. In later design stages, additional investigations on the stock might be required.

1 Introduction

1.1 Context

The construction industry is responsible for a significant portion of the detrimental effects caused by humans on the environment. The industry of concrete, the most ubiquitous construction material, is particularly harmful to the climate and biodiversity. For example, the production of cement, a key component of concrete, is accountable for 6 % of all anthropogenic greenhouse gas (GHG) emissions in Switzerland [1]. Concrete is also the largest source of construction waste in Switzerland with a share of 34% [2]. Concrete waste is mainly generated during demolitions often decided by socio-economic reasons, when the components of the obsolete building are still in good conditions and could have served longer. The industry today favors energy-intensive recycling of concrete waste, crushing it to produce recycled concrete aggregates used to partly replace natural ones in new concrete mixes. The need for at least as much cement in those so-called “recycled” concrete mixes leads to no reduction in GHG emissions [3]. An environmentally more efficient strategy is the direct reuse of concrete components.

Little-known and rarely implemented, the reuse of concrete components from obsolete buildings in new projects is a circular approach that can reduce the detrimental impacts of concrete construction. When reusing, the components of obsolete buildings are carefully dismantled without being crushed. Once salvaged, components are cleaned, possibly repaired or trimmed, and reused without many transformations in a new project, maintaining their shapes and embedded structural properties. In addition to maintaining the embodied energy and history of the reused components, reuse allows the construction industry to reduce demolition waste and material consumption. To make it possible, reuse requires a detailed assessment of components at an early stage of the deconstruction project, a careful selective deconstruction process, and finally synchronization with a receiver project that will reuse the components and whose design should be tailored to the specificities of reuse.

1.2 Objectives

This document focuses on the assessment of existing and soon-to-be deconstructed reinforced concrete (RC) structures, aiming at characterizing and promoting the potential for reuse of its components. It first describes the **reusability assessment** of the RC components based on three criteria: damage, use and intervention. The reusability assessment is a tool to help designers in deciding the best use for a reclaimed RC component. A step-by-step protocol is then detailed to complete the **resource assessment** of precast and cast-in-place load-bearing RC structures of buildings, including component inventory and categorization, damage assessment, investigations on geometry and materials, and other relevant quantitative and qualitative information on the components. The information collected in the resource assessment helps planners to prioritize the reuse of the components in the best conditions, with the largest volume share and thus with the largest embodied global warming potential. The results of the resource assessment in combination with the reusability assessment tool serves as a base for designing and planning the future reuse applications of their components.

These assessments allow planning the deconstruction of the obsolete structure using methods that will subsequently facilitate the reuse of the components. They also reduce the unknowns when designing the new structure with the components described by the assessment. Figure 1 illustrates how the reusability and resource assessments integrate into the project phases of both the obsolete structure – i.e. the *donor* building – and the new building – i.e. the *receiver* building.

1.3 Scope

The methodology is developed for load-bearing RC structures or self-supporting RC components such as facade elements. The following building components are considered as out-of-scope for the protocol:

- › Structural components not made of concrete
- › Non-bearing partitions, doors and windows;
- › HVACS technical equipment;
- › Any electrical equipment;
- › All finishing layers;

- › Furniture.

The reusability and resource assessments are based on existing documentation, visual inspection and limited testing of the donor structure prior to its deconstruction. Some aspects, listed below, are not addressed by these assessments:

- › Loading history of the component: It is expected that the assessed structure was submitted to standard loads for its current or, if known, past use. Exceptional loading applied on the structure or its components since its construction until the deconstruction are not explicitly considered. Only resulting damages will be noted if visible.
- › Deflection of the component: Existing and non-reversible deflections of the component due to cracking or long-term effects are not considered, unless obviously visible. It is expected that deflections are within standard limits. However, this assumption should be verified after deconstruction of the component and prior to its reuse.
- › Deconstruction feasibility: The feasibility of extracting a component from the donor building is not evaluated in the reusability assessment.
- › Damages caused during deconstruction: Any damage that could occur during the extraction of the component from the donor structure and during its handling is not considered, as the assessment is prior to these steps. Additional visual inspections should be planned after deconstruction and prior to reassembly in the receiver structure.

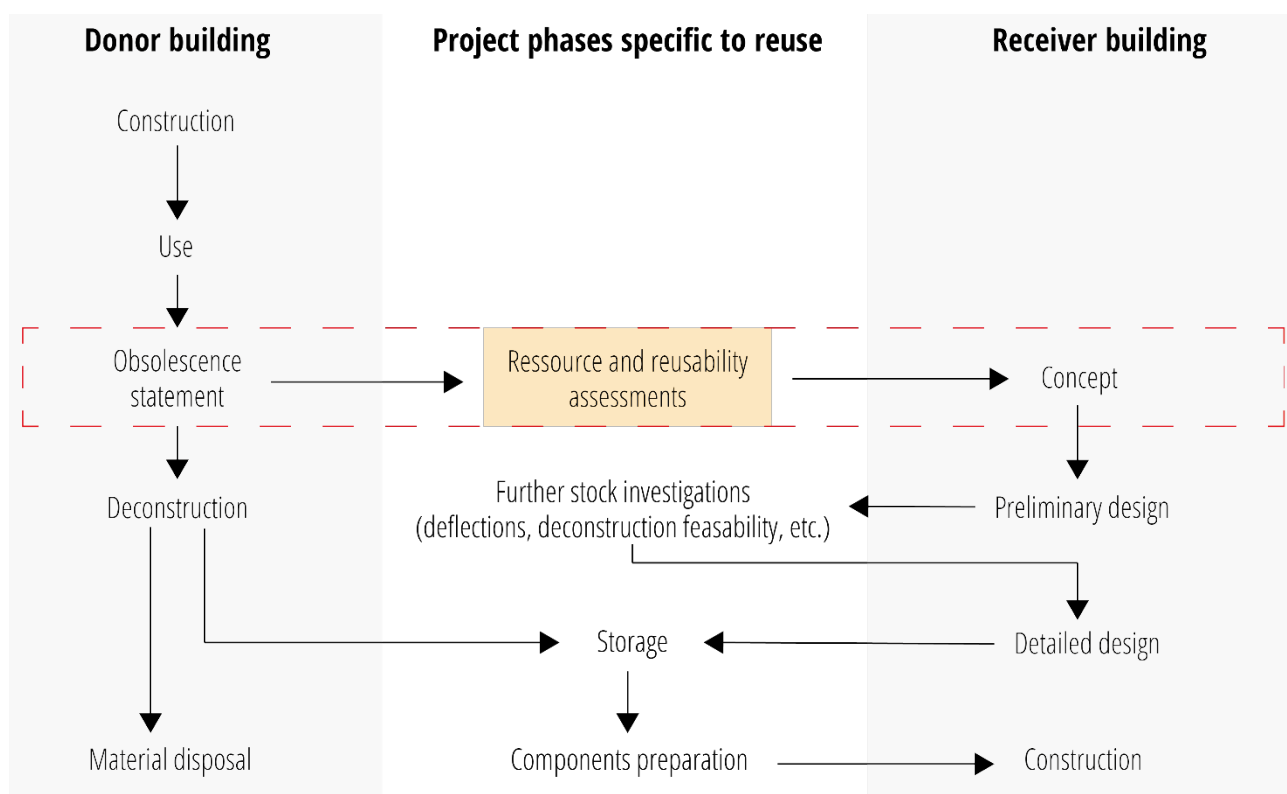


Figure 1. Resource and reusability assessment in the project phases

2 Reusability assessment

2.1 Preamble

In the field of existing structures, the condition assessment of the structural, and non-structural, components highlight damages and detrimental anomalies. These have influence on the durability, serviceability, and structural safety of the structural components and eventually of the whole structure. Thus, this assessment results in intervention measure recommendations to meet a desired performance of the structure. The condition assessment of existing structures, and mainly existing bridges, is already widely reported by many authors in the literature. Ways of assessing the condition of structures based on visual inspection are explored [4–6], as well as using sensor measurement [7] and using new technologies, such as Unmanned Aerial Vehicle (UAV) [8–10] or 3D-scanning and virtual reality [11].

Visual inspection is a simple, effective and economic method to quickly obtain an estimation of the individual condition of the components of a structure [12]. It can be performed by any engineer, which therefore also involves a high degree of subjectivity [12–14] partly erased through methods or protocols [6,11,12,15]. When visually inspecting the condition of an existing structure, several factors are highlighted to assess the condition of the structural components as objectively as possible. Bertola and Brühwiler [6] describe the component condition as a product of the degradation state and the risk class to propose adequate intervention measures. As in many other studies, the degradation state is characterized by the extent and the severity of the damages [16,14,11]. The risk class is characterized by the consequences of the component failure on the whole structure's safety [16,14].

Bad condition or incorrect use of a reclaimed component would increase the risk of inappropriate behavior of the new construction. Therefore, in a reuse strategy, the reusability assessment gives indications on the best way to reuse a RC structural component to avoid downcycling considering preexisting damages (damage class), the intended use in the receiver structure (use class) and the planned interventions on the component prior to reuse (intervention class). The following sections describe the proposed method for assessing the condition of RC components for reuse and obtaining a reusability grade. It is based on the risk-based methodology by Bertola and Brühwiler [6] for bridge condition assessment by visual inspection. The damage class is the only factor that is established in the resource assessment procedure (see section 3), the other two factors depend on the receiving project and serve as decision support tools to choose a reasonable reuse strategy.

2.2 Reinforced concrete damage types

2.2.1 Generalities

Damages of RC can occur when it is exposed to certain climatic conditions. These damages affect the durability of RC and can lead to serviceability and structural safety problems. The durability of RC evolves with time and is described by 1) the initiation phase, during which the element becomes vulnerable due to loss of protection and exposure to harmful agents, and 2) the degradation phase, when the bearing capacity of the component decreases. Common damages to RC are described in the following sections. Many of them can be detected by visual inspection.

2.2.2 Corrosion of steel reinforcement

The corrosion of steel reinforcement leads to damages of the concrete surface, to degradation of steel reinforcement sections and thus a reduction in its structural resistance. The following three conditions must be met to initiate corrosion of rebars: (1) presence of oxygen, (2) presence of humidity and (3) depassivation of steel rebars either by the presence of chlorides or by the carbonation of the concrete [17]. In RC structures, the cover concrete layer protects the steel reinforcement from external agents. The basic environment of the concrete prevents the corrosion of the rebars by creating a thin protective layer at the interface of these two materials.

Chlorides - e.g. coming from deicing salt - can reach the rebars when the cover concrete layer is too thin or damaged – e.g. cracked. They reduce the pH and, when a certain concentration of chloride is reached, the protective layer of the steel reinforcement becomes unstable. The steel reinforcement is then depassivated and, in the presence of water and oxygen, the corrosion of the rebars starts. Corrosion caused by chlorides is a localized corrosion process. During a visual inspection, this process can be observed by the presence of localized corrosion spots on the concrete surface, by localized spalling of the concrete cover and by localized corrosion of the steel reinforcement.

Carbonatation is the chemical reaction between the carbon dioxide (CO_2) contained in the air and the calcium hydroxide ($\text{Ca}(\text{OH})_2$) dissolved in the pore solutions of concrete. It produces solid calcium carbonate (CaCO_3) which tends to harden the affected concrete, while reducing the pH of the pore solutions. If the depth of carbonatation is greater than the concrete cover thickness over the steel reinforcements, then the latter are depassivated and, in presence of oxygen and water, corrosion starts. Corrosion caused by concrete carbonatation is a generalized corrosion process. During a visual inspection, this process can be observed, as shown on Figure 2(a), by a concrete spalling over a relatively large area and by generalized corrosion of steel reinforcement.

In all buildings except parking areas, chlorides are not present. In addition, humidity is generally low inside buildings. Therefore, it is uncommon for corrosion of steel reinforcement to occur inside buildings. In any case, nowadays, methods are available to determine the chloride concentration, the depth of carbonatation, and the related corrosion risk or rate of the rebars [18].

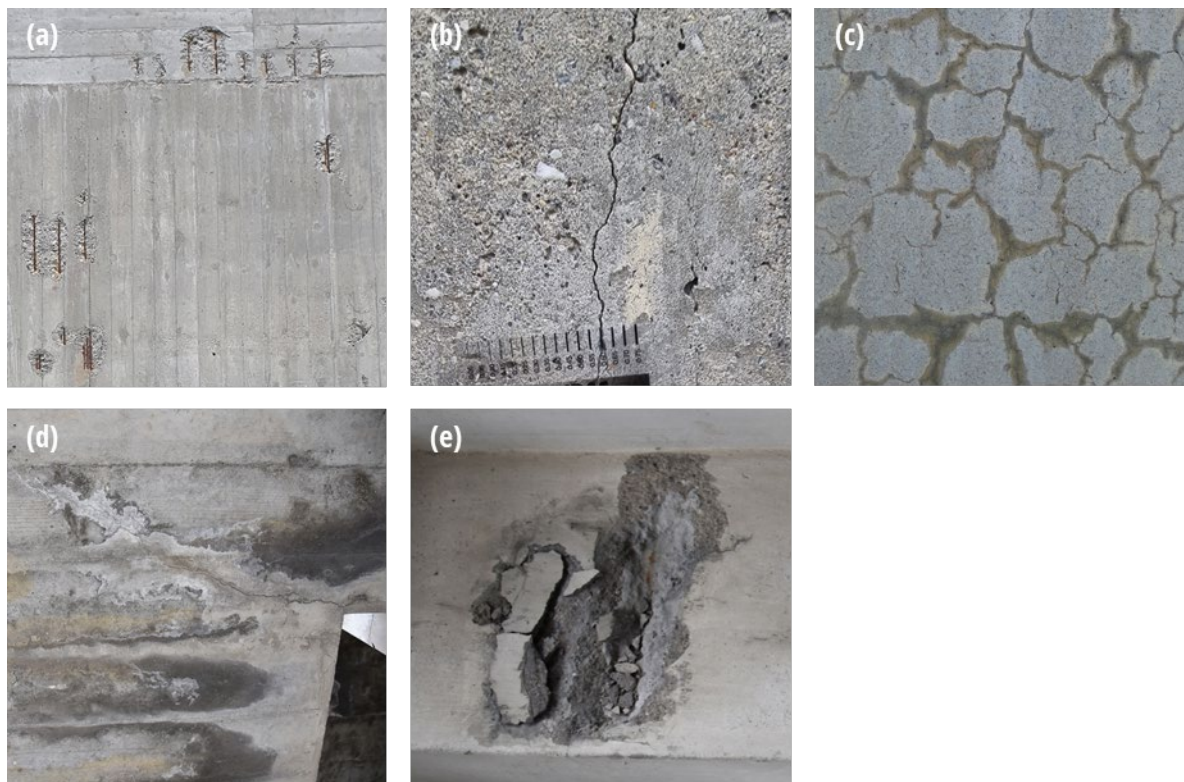


Figure 2. RC damages: (a) steel rebar corrosion; (b) cracking; (c) cracking pattern due to alkali-silica reaction (photo by Shinkolobwe, CC BY-SA 4.0 via Wikimedia Commons); (d) water damages; (e) concrete spalling.

2.2.3 Cracking

Cracking of concrete is a normal phenomenon in service, usually characterized by flexural cracks with an opening up to 0.3 mm. Nevertheless, abnormal cracks can also be found due to various causes such as: exceptional loads, bad detailing or execution, restrained deformations due to loads or temperature change, alkali-silica reaction, etc. These cracks can have consequences on structural safety and serviceability, notably due to a loss of rigidity. They also affect the durability of the components by facilitating the penetration of harmful substances (water, chlorides) and hence favoring the start of corrosion of the steel reinforcement. During visual inspection, large number of cracks or large crack openings should be noted, Figure 2(b).

2.2.4 Alkali-silica reaction

The alkali-silica reaction is a slow degradation process which is due to the chemical reaction between the “reactive” aggregates and the alkalis present in the pore solution of concrete. The alkali-silica reaction occurs if the following three conditions are met: (1) presence of reactive aggregates, (2) presence of humidity, (3) sufficient alkali concentration. The resulting silica gel causes the concrete to expand and subsequently crack. The consequences are a loss of mechanical properties: decrease of tensile and compressive strengths and decrease of elastic modulus. During visual inspection alkali-silica reactions can be detected by the presence of a slightly brown crack mesh, as shown

on Figure 2(c). Humidity is generally low inside buildings and it is thus highly uncommon for alkali-silica reactions to occur inside buildings. In case of suspicion, methods exist to evaluate the presence and progression of alkali-silica reaction in concrete.

2.2.5 Water damages

Wet streaks or efflorescence show the circulation of water through the concrete. When these are important or when limescale stalactites are present, corrosion of the reinforcement is to be expected. An example of water damage is shown on Figure 2(d).

2.2.6 Concrete spalling or chipping

The spalling or chipping of concrete can be due to an external impact but also to frost if water saturation in the concrete pores is high. When the temperature is low, the water in the pores freezes leading to an increase of its volume which then makes the concrete spall and chip. During the visual inspection, this damage is identified by the spalling or chipping of the concrete cover without any corrosion of steel reinforcements, Figure 2(e).

2.3 Damage class

The **damage class** is defined by visual inspection as proposed by Bertola and Brühwiler [6] for an existing structure. It is the most complex task of the reusability and resource assessment of structural components because damages must be properly interpreted and understood. The visual inspection is performed on the obsolete structure before its deconstruction and included in the resource assessment, as described in section 3.5. Damage classes are described in Table 1 and illustrated on Figure 3. Grades are based on the extent (local, wide or extensive), the severity (light, moderate or heavy) and the incidence (unique or frequent) of the damage. Only a local damage can be unique or frequent. Examples of the different severity levels are:

- › Light damage: Fine cracks, water stains or chipped concrete;
- › Moderate damage: Cracking, spalled or chipped concrete, efflorescence, corrosion spots;
- › Heavy damage: Heavy cracking, concrete spalling and exposed corroded rebars.

Damage class (condition)	Damage description			Consequences
	Extent	Severity	Incidence	
A (Good)	None	-	-	-
	Local	Light	Unique	
B (Acceptable)	Local	Moderate	Unique	Durability
	Wide	Light	-	
C (Deviant)	Local	Light	Frequent	Serviceability
	Local	Heavy	Unique	
	Wide	Moderate	-	
	Extensive	Light	-	
D (Bad)	Local	Moderate	Frequent	Serviceability or security
	Wide	Heavy	-	
	Extensive	Moderate	-	
E (Failure)	Local	Heavy	Frequent	Security
	Extensive	Heavy	-	

Table 1. Damage class definition

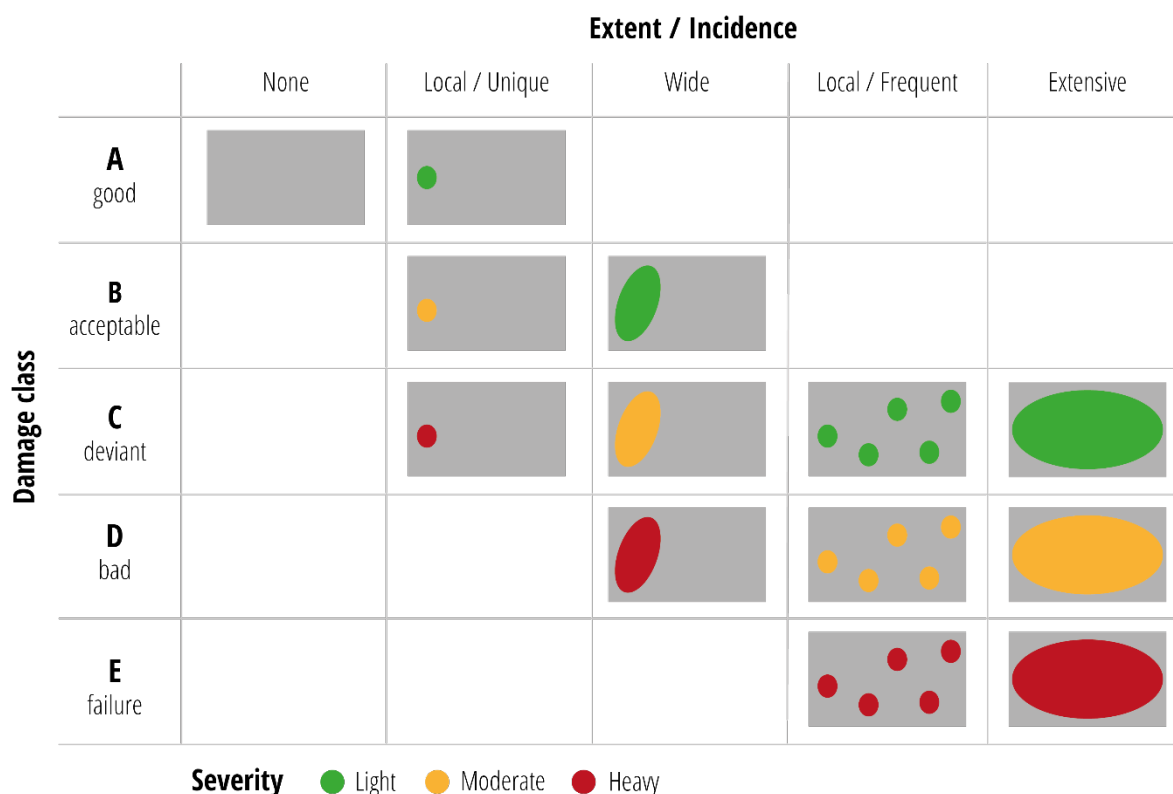


Figure 3. Damage class illustration

The severity of damages is not always assessable by visual inspection. Thus, the damage class can be corrected after further investigations, such as those described in sections 3.6 and 3.7. Some examples of possible corrections are given in Table 2.

Investigation	Observation	Correction
Concrete carbonation	Depth of carbonation higher than the rebars cover	Reduce the damage class by 1 level
Rebar corrosion	Loss of rebar area up to 10%	Maximum damage class = C (Deviant)
	Loss of rebar area between 10% to 40%	Maximum damage class = D (Bad)
	Loss of rebar area of more than 40%	Maximum damage class = E (Failure)
Alkali-silica reaction		

Table 2. Damage class correction after further investigation

2.4 Use class

For the reusability assessment, the structural demand of a component is defined by how it could or will be used in the receiver structure, not by how it is currently used in the donor structure. The use class of a component depends on its stability in its new use – defined in Table 3 – as well as its exposure to water – see in Table 4 – which relates to its durability. Once the stability class and water exposition level have been fixed, the use class can be defined, as introduced in Table 5.

Stability class	Failure consequence	Consequence for
No stability criteria	Limited	Serviceability only
Self-stable	Moderate	Structural safety or serviceability
Stable under external loads	Important	Structural safety and serviceability

↑
Downcycling

Table 3. Stability class definition (adapted from Bertola and Brühwiler [6])

Water exposition		Exposition class according to SIA 262 [19]	Exposition condition
Lightly exposed	Always dry	X0, XC1	Interior component of a building with low humidity and not subject to frost, de-icing salts, sea salt, etc.
Moderately exposed	Moderately humid	XC3, XD1, XD3, XF1, XF2	Interior component of a building with high humidity, outdoor surfaces protected from rain, surfaces exposed to frost, salt fog, etc.
Highly exposed	Alternately wet and dry	XC2, XC4, XD2a, XD2b, XF3, XF4	Surfaces exposed to rain, wet for long periods, surfaces exposed to de-icing salts and frost.

Table 4. Exposition class definition

Use class	Lightly exposed	Moderately exposed	Highly exposed
No stability criteria	I	II	III
Self-stable	II	III	IV
Stable under external loads	III	IV	V

Table 5. Use class assignment based on the stability class and the exposition class

2.5 Intervention class

Interventions on the components are possible and will affect their reuse potential with regards to their damage and use classes. Defining the needed interventions on the components is however not the goal of the reusability and resource assessments, as this should be done during the design phase of the receiver project. In other words, decisions related to the level of interventions on the reused components must be balanced with all other decisions and givens of the project. However, it is useful to understand that various levels of interventions can be carried out which is translated into the intervention class in Table 6. The intervention class describes the actions that could be made on the component to modify, restore or strengthen it.

Intervention class	Maintenance measures	Geometry modifications
a	No action	No further cutting after extraction
b	Preventive maintenance, light strengthening	Simple cutting
c	Curative maintenance, rehabilitation, medium to important strengthening	Complex cutting or modification

Table 6. Intervention class

It must be ensured that interventions remain proportionate from an economic and environmental point of view. The economic proportionality consists in comparing the cost and the benefit (risk reduction) that the interventions generate. This principle is already used for existing structure maintenance, as described in Swiss standard SIA 269 [20], especially in the field of maintenance against seismic events [21]. The environmental proportionality consists of comparing the environmental impact (i.e. in kgCO₂ equivalent) between the intervention process and the production of the component with new RC. If the impact is higher for the intervention, it is not proportionate. If the interventions are disproportionate from an economic or environmental point of view, then the reuse of the RC component should be reconsidered or questioned.

2.6 Reusability grade

The reusability assessment of a RC component depends on the damage class, the use class and the intervention class, as defined in the previous sections, and results in a reusability grade. The description of the reusability grade is presented in Table 7 and the graph presented on Figure 4 aims at helping engineers during the design process to choose the best reusability grade for a component according to the combination of the three criteria. The graph of Figure 4 is a working tool and requires the analysis and good judgment of engineers to be interpreted and used correctly. It does not give a unique solution but guides engineers to provide an objective, proportionate and adapted analysis of the situation by trying to slow down as much as possible the downcycling of the reclaimed RC component.

Reuse grade	Reusability	Description
1	Reusable	The component can be considered as good as new. Monitoring of the component in the receiver structure should not be different from standard procedure in any new structure.
2	Reusable with occasional controls	The component can be reused. Nevertheless, some small damages or anomalies can affect the durability of the component. It should be inspected occasionally with a special emphasis on monitoring the evolution of these preexisting damages and anomalies. Interventions may be required earlier than for a new structure so as not to affect serviceability and security.
3	Questionable reuse	The reuse of the component is questionable as it cannot be guaranteed that the degradation process is under control. It is not excluded that the condition of the component degrades with resulting impacts on serviceability and structural safety. A reduction in the resistance of the component must be considered (for instance due to a loss of rebar section because of corrosion). A regular and careful control of the component must be carried out if it is reused. The cost and energy required to reuse such component makes the strategy questionable.
4	Not recommended reuse	The component presents damages that affects its structural safety. The damages are difficult to control, and the component resistance is greatly reduced. Even regular checks should not be sufficient to guarantee the structural safety of the component. Reuse of the component is not recommended.
5	Not reusable	The component shows damage that greatly affects its structural safety. It is not possible to reuse it under any circumstances.

Table 7. Reuse grade definition

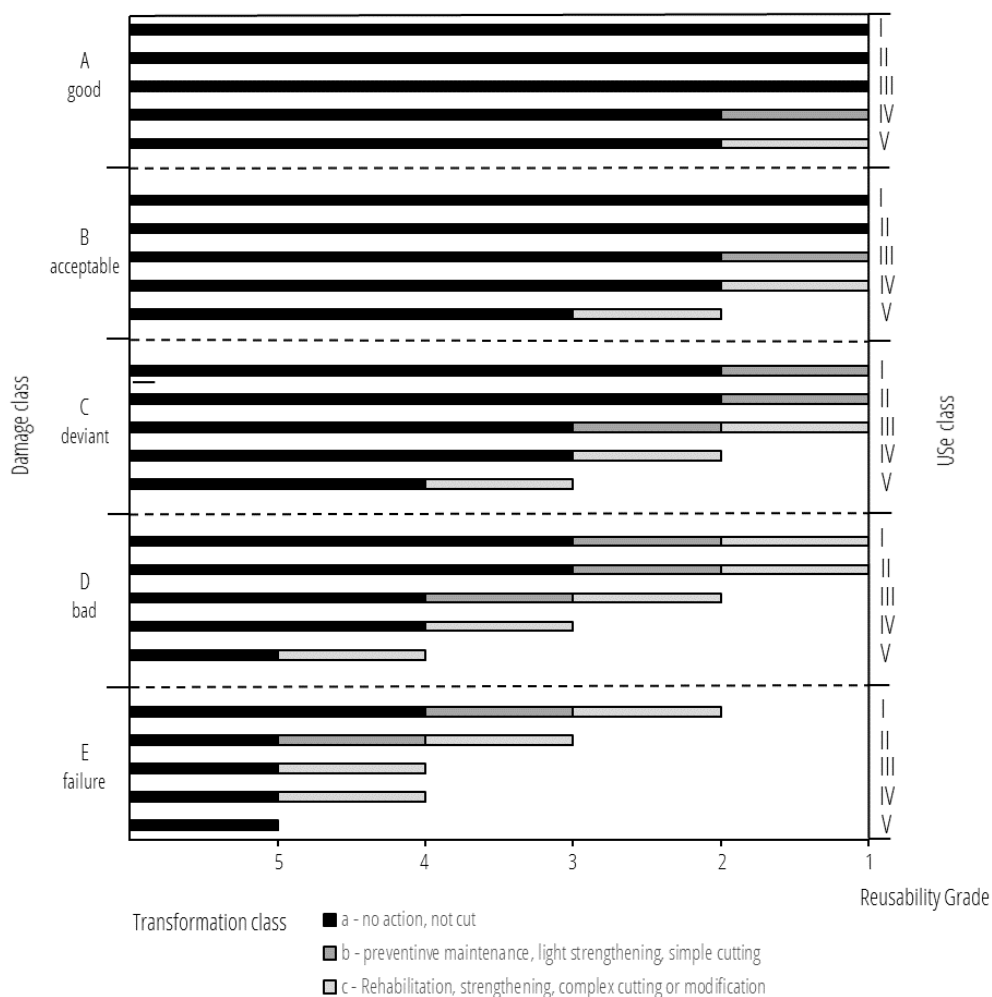


Figure 4. Reusability assessment

Figure 4 expresses that a component with a damage class A is as good as new and can be reused for any use class (see Table 5). For higher use classes IV and V, when the component might be exposed to water while resisting to external loads, preventive maintenance, transformation or even strengthening (transformation class b or c) can be required to obtain a reusability grade 1. Indeed, most components available for reuse will have been designed under former standards and the transformation will ensure that the component meets current standards for concrete structures. For example, it might be needed to increase the concrete cover or to add flexural strengthening.

As the level of damages increases (class B and C), transformation of components will always be necessary to reach a reusability grade of 1 for a use class implying external loads or exposure to water (class III or higher). In the case of a damage class D or E, it is nearly impossible to reach a reusability grade of 1 and the reuse of such components without major transformations is questionable or not recommended. For this reason, components falling in those damage classes are most of the time discarded.

Figure 5 illustrates an example facade panel used to demonstrate how the reusability assessment tool can be used to evaluate the options for a future reuse in a new receiver structure. This facade panel shows two small local zones of concrete spalling and one localized corroded rebar – its **damage class is C** (deviant condition). Two reuse variants are studied. For each of them, the chosen transformation class will change the reusability grade and give indication on the relevance of preliminary design choices.



Figure 5. Example of the reusability assessment of a facade concrete panel

1. The panel is reused for the same function, a facade panel. It must therefore be self-stable and will be exposed to rain. The **use class is IV**.
 - > **Transformation class a:** If no maintenance or transformation is planned on the panel, its **reusability grade is 3**. Its reuse is questionable as it will require regular and careful monitoring which might be unwanted for a new structure.
 - > **Transformation class c:** With some rehabilitation and strengthening, the **reusability grade is 2**, which means that the component can be reused but that it should be inspected on a more regular basis than a new structure. In this case, the interventions might be a cut to completely remove the damaged area and eventually the application of mortar to increase the cover thickness of the rebars.
2. The panel is reused as pavement for an outdoor parking zone. There is thus no stability criteria, but it will be highly exposed to water and de-icing salts. The **use class is III**.
 - > **Transformation class a:** If no maintenance or transformation is planned on the panel, its **reusability grade is 3**. Its reuse is questionable as it will require regular and careful monitoring which might be unwanted for a new structure.
 - > **Transformation class b:** With some preventive maintenance or transformation to repair or remove the damaged parts, the **reusability grade is 2**, which means that the component can be reused but that it should be inspected on a more regular basis than a new structure. In this case, the interventions might be the treatment of the corroded rebars and the application of a repair mortar on the damaged areas, but no major geometrical transformation.

- > **Transformation class c:** With some rehabilitation and strengthening, the **reusability grade is 1**, which means that the component is just as good as a new one. In this case, the interventions might be a cut to completely remove the damaged area or the application of mortar to increase the cover thickness of the rebars.

According to the above the component of Figure 5 is best reused for a use class of III or lower. To obtain a reusability grade of 2 or more, it should be transformed, by repairing or removing the damaged zones.

3 Resource assessment protocol

3.1 Preamble

The resource assessment of an obsolete building intends to provide quantitative and qualitative information on the stock of RC components available for reuse. Protocols for resource assessments for reuse exist – e.g. methods proposed by the FCRBE European project [22] – but very few are applied specifically to structural components and none to RC structural components.

The following section proposes a protocol to inventory and evaluate the resources of a RC load-bearing structure. First, existing data on the donor building is collected. This input information allows planning the resource assessment, which is divided in steps presented on the flow chart of Figure 6 and detailed in sections 3.2 to 3.8. This protocol provides all info needed to carry out the reusability assessment presented in section 2. The collected information is summarized in a report, including factsheets for each component type – see section 4.

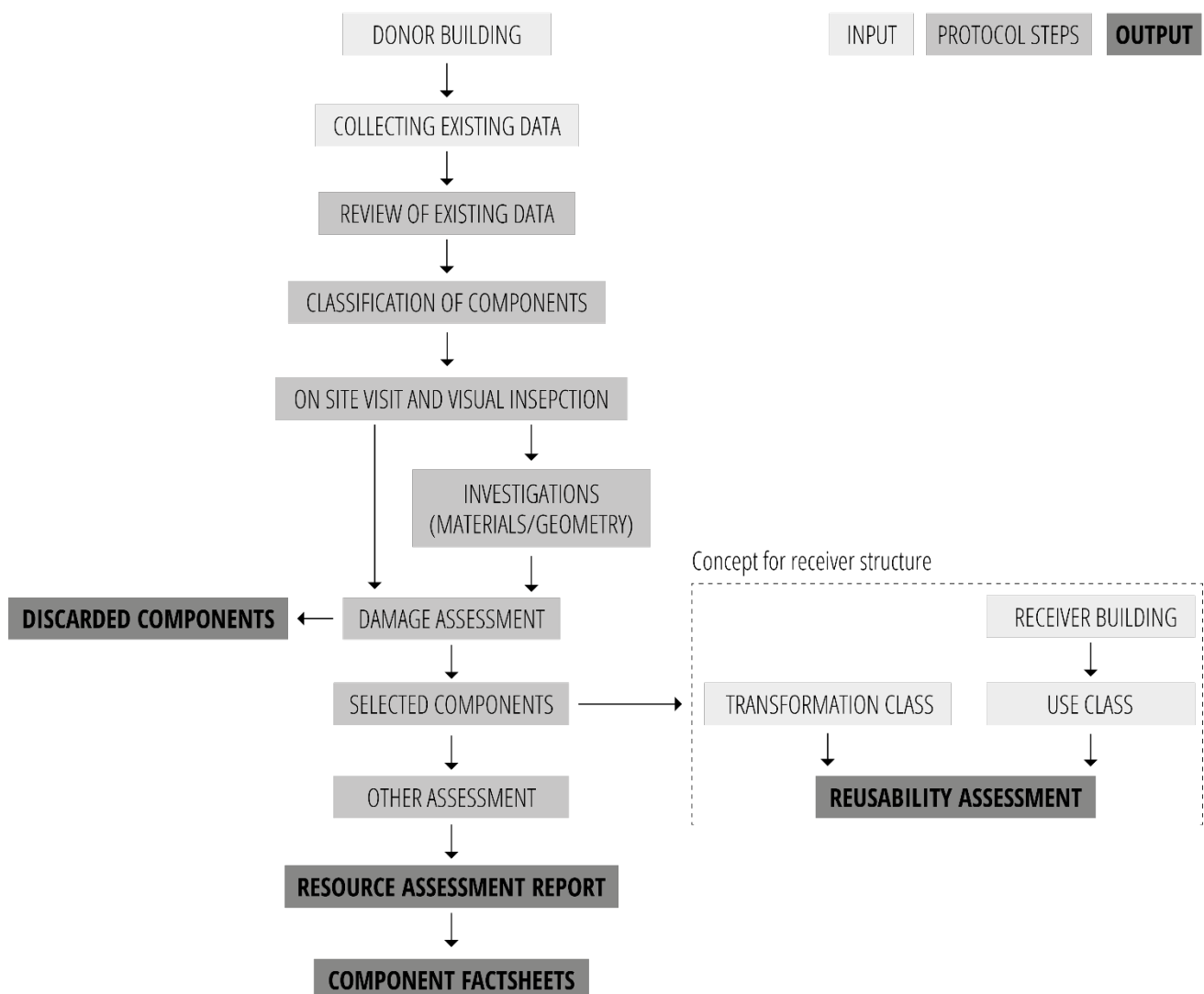


Figure 6. Flow chart describing the resource assessment protocol

3.2 Review of existing data

Reviewing existing data is the very first step, prior to on-site visits. It consists in collecting basic data on the building and its structure – such as location, construction year, use, dimensions, structural system, material properties, etc. – and identifying missing information to be collected in the next steps of the protocol. Documents such as construction and renovation blueprints and drawings by architects and engineers as well as technical reports are collected and reviewed.

Existing blueprints provide information on the dimensions of the structural components through plan views, cross-sections and elevations. The steel reinforcement layout and material properties (concrete and steel grades) are found on engineering drawings.

The building pollutant diagnosis report is an essential document when planning the deconstruction and future reuse of components and must be prepared by experts at an early stage of the project. It discusses the potential presence of toxic substances such as asbestos, PAH (polycyclic aromatic hydrocarbons), PCB (polychlorinated biphenyl), etc. The presence of these substances limits the reuse potential of the concrete components and impact the deconstruction and preparatory work of the RC components.

Any other existing documents on the building and its structure (e.g. transformation plans, deconstruction feasibility study, etc.) can contain interesting information and must be reviewed if available. To complete the data on the building, research is also done in public archives and specificities of the building is researched in the scientific and technical literature. Notably, information on construction techniques and structural systems can be found in archived historical technical publications.

3.3 Classification of components

Using the existing blueprints, components are inventoried and classified in categories and types to simplify the assessment. Main categories relate to their structural function: (1) facades, (2) slabs, (3) walls, (4) beams, (5) columns, (6) staircases, etc. Then, components with the same characteristics (e.g. material type, construction methods or assembly) are grouped by types with subtypes for every given dimension. These categories, types and subtypes are used to complete the precise inventory of the studied structure.

3.4 On-site visits and visual inspection

After classifying the components, an on-site visit is carried out, having the following goals:

- › verify the consistency between the collected information from the existing data and what is built;
- › conduct a visual inspection of the structural components to identify damages (section 3.5), aesthetics (section 3.8.1) and accessibility (section 3.8.2);
- › discard any component type with low reuse potential because of a damage class equal to D or E (bad condition or failure, see section 2.3).
- › define the location of the destructive investigations (section 3.7.1);
- › carry out non-destructive investigations (section 3.7.2);

3.5 Damage assessment

The damage assessment is carried out with the method described in section 2.3. The damage class is defined for each component type by visual inspection and is corrected after the investigations presented in section 3.6 and 3.7.

The assessment is done for each component type. When all components of a type are visible and accessible for the inspection, each component is individually graded and proportions for each damage class are then obtained for this component type. Otherwise, a single grade is given to the type based on localized inspections.

Component types with a high proportion of damage class D or E (bad condition or failure) are discarded and not considered further for the resource assessment. This avoids unnecessary work on components that have little chance to be reused as is.

3.6 Investigations on geometry

If data is insufficient (unavailable or incomplete drawings), the geometry of the structure is measured on site. Depending on the amount of information, different methods can be used such as:

- › manual measurements with rulers and measuring tapes;
- › drilling to check overlay and slab thickness;
- › removing cover concrete to check reinforcement layout or connection details;

- › point surveying using a total station theodolite;
- › 3D scans using a LiDAR scanner or photogrammetry.

Point surveying and 3D scans can also be used to verify pre-existing deflections in components if observation show that they might be outside standard limitations.

3.7 Investigations on materials

3.7.1 Destructive investigations

Destructive investigations allow verifying the material properties and condition of reinforcing steel and concrete. The number of destructive tests is preferably kept to a minimum as they are costly and damage the components. The types and number of tests depend on the amount of pre-existing information and observed damages. Their results are used to calibrate more extensive non-destructive tests (see paragraph 3.7.2). Below is a non-exhaustive list of investigation methods and tests intended to evaluate the properties and condition of a concrete structure.

Steel rebars

To expose the rebars, concrete cover is mechanically removed to create an opening. For a specific location of the concrete structure, such an opening allows defining the cover concrete thickness, the arrangement and the diameter of the rebars as well as checking for any steel corrosion. It also allows sampling the steel rebars. These samples are then tested in tension to obtain their yield and maximum strength. The results are then analyzed to obtain the actualized characteristic value of the yield strength, according to the SIA 269/2 standard for existing concrete structures [23]. The Steeldata database by EMPA [24] can also allow identifying the steel type and characteristics based on visual observation in an opening, therefore preventing the need for sampling and testing.

Concrete

Concrete is sampled by extracting cores, used for different test types. It is recommended that a minimum of three cores is extracted for each test types and for every suspected concrete type of the structure. To correctly identify a concrete type, the following parameters are minimally evaluated:

- › concrete density, by measuring the volume and the mass of the extracted cores;
- › compressive strength of concrete, obtained as described in the SN EN 12504-1 standard [25] and used to calculate the actualized characteristic value for design according to the SIA 269/2 standard for existing concrete structures [23];
- › elastic modulus of concrete, obtained as described in the SN EN 12390-13 standard [26];
- › carbonatation depth, measured on the split surface of the cores used for the compressive strength tests, using phenolphthalein, in accordance to the SN EN 14630 standard [27].

If the concrete component shows some suspicious cracking patterns, as described in section 2.2.4, the potential presence and progress of the alkali-silica reaction is verified by scanning electron microscopy (SEM) on lamellas cut from a core. The presence and concentration of chlorides in the concrete is verified for structures that were exposed to deicing salts or located by the sea. It is measured at various depths of a core, according to the SN EN 14629 standard [28].

3.7.2 Non-destructive investigations

If required, non-destructive investigations are conducted to complete the data obtained with destructive testing and verify the consistency of the material properties on larger areas without causing further damages to the components. The results of the destructive testing are used to calibrate the non-destructive tests. Below is a non-exhaustive list of non-destructive investigation methods and tests intended to evaluate the properties and condition of a concrete structure.

Steel rebars

Rebar layout can be obtained using a ferroskan or a ground penetrating radar (GPR). The ferroskan also estimates rebar diameter. These measurements are calibrated by measurements near the destructive openings. The yield strength of steel rebars can be estimated with the construction year of the building and the standards in effect at the time.

Concrete

A well-known method to estimate the compressive strength of concrete is the Schmidt rebound hammer (Figure 7). With springs and a sliding mechanical mass, the rebound hammer measures the ratio between mass kinetic energies before and after impact which is then correlated to the compressive strength of the concrete component [29]. It is basically a surface hardness tester and the results are influenced by carbonatation [30]. For this reason, a first series of on-site rebound-hammer measurements are correlated with the results of the compressive tests on extracted cores. Once the correlation is established, the rebound hammer is used at various location to confirm the concrete resistance. The results of the measurements are analyzed as for test results on cores, using the mean and the standard deviation to obtain the characteristic value of the compressive strength, as prescribed in the SIA 269/2 standard for existing concrete structures [23].

GPR measurements allow verifying the humidity as well as the chloride concentration in the concrete. It also shows the presence of voids, cracks or other damages [18].

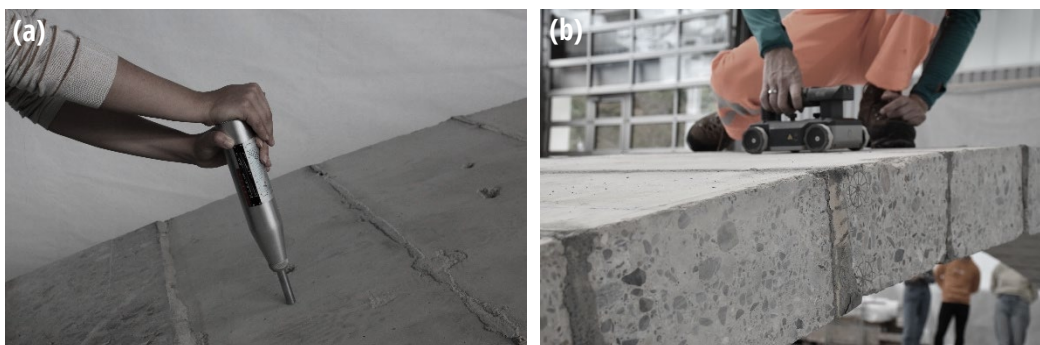


Figure 7. Non-destructive measurements: (a) Schmidt rebound; (b) ground penetrating radar.

3.8 Other assessments of components

3.8.1 Aesthetics

The aesthetics of the components is mainly defined by the color and the finishing of the concrete surface, evaluated by visual inspection. The color of the components is matched to a RAL color chart number. As the color is not necessarily uniform over the entire surface the closest RAL correspondence is chosen and information about shades or tints (for example yellow or blue tint) is also given in the factsheet. The finish of the concrete surface depends on the type of formwork used during construction which leaves some patterns or marks on the surface. This observation is made directly on the components if their surface is visible. When the concrete surface is not visible, information on the overlays, such as flooring or painting, is recorded.

3.8.2 Accessibility

Accessibility characterizes the ease and speed with which the component is made available during the deconstruction of the building and is ranked on four levels:

- › easy, if no other components are dismantled before the concerned component;
- › moderate, if one or two other components are dismantled beforehand to allow the disassembly of the concerned component;
- › difficult, if three or more components are dismantled beforehand to allow the disassembly of the concerned component;
- › very difficult, if all the building is dismantled beforehand.

3.8.3 Cross-section resistance

The cross-section moment resistance of the component is estimated using standard models for RC sections. This value is useful when including the component in the predesign of a receiver structure and should be further confirmed in later stages of the design process according to chosen boundary conditions – e.g. simply supported or continuous systems.

3.8.4 Volume significance

The volume significance is the portion of the total concrete volume of the building, $V_{building}$, that the considered type of component represents, $V_{component}$. This number shows the importance of a component in relation to the whole structure and helps choosing which components must be prioritized in the reuse strategy to maximize the volumes of material saved from landfill.

$$Volume\ significance\ (\%) = \frac{V_{component}}{V_{building}}(1)$$

3.8.5 Environmental impacts

Environmental impacts due to the fabrication process of the components and their subsequent demolition and elimination is expressed by greenhouse gas emissions (in kgCO_{2eq}) or primary energy demand (in kWh_{oil-eq}). These indicators are calculated using the weight of the component and equivalent factors available in the swiss KBOB database [31]. Assumptions made to calculate these indicators are described in the report. As for the volume significance, calculating the embodied environmental impacts of the components allows identifying which components must be prioritized in the reuse strategy to significantly reduce emissions and energy demand.

4 Reporting

4.1 Preamble

The resource assessment report gathers all information collected through the protocol described in chapter 3. This information is needed to plan the deconstruction of a donor RC structure and design the future reuse of its components. The reusability potential can then be graded with the tool described in chapter 2.

The report is composed of the following parts:

1. Introduction: basic information on the building such as its location, construction year, use and basic structural system.
2. Resource assessment reporting, including a brief descriptions of the methods and the results obtained (section 4.2)
3. Summary tables of the discarded and selected components (section 4.3)
4. Factsheets for every component types, summarizing all useful information (section 4.4 and Annex B)

Annex A provides a checklist of all information expected in a resource assessment report for a RC structure. It can be used to evaluate the quality of a report.

4.2 Resource assessment reporting

Table 8 summarizes the information expected in the resource assessment report based on the steps of the protocol presented in chapter 3.

Step	Information to be provided in the report
Review of existing data	The available documents are listed in the report. All relevant information found in the existing documentation is summarized in the report.
Classification of components	A figure showing the location of component types is included. All categories, types and subtypes of components are described and presented in a summary table (section 4.3).
On-site visits and visual inspection	The date(s) of the visit and the name(s) of the person(s) present are mentioned in the report. A brief description of the main observations and work carried out is also included.
Damage assessment	The damage observed on the discarded components is described with photos depicting them. The condition of the selected components is presented in the summary table and the factsheets.
Investigations on geometry	The measurements are located on a plan view of the assessed building. All measurement results are given in the report.
Destructive investigations on materials	The samples are located on a plan view of the assessed building. All test results are given in the report.
Non-destructive investigations on materials	The measurement zones are located on a plan view of the assessed building. All test results are given in the report.
Aesthetics assessment	The color and the finishing are described in the component type factsheet, with the closest RAL color chart number.
Accessibility assessment	The level of accessibility is mentioned in the component type factsheet.
Cross-section resistance	The values for each component sub-type should be reported in the factsheet.
Volume significance	Volume significance values for each component sub-type is reported in the summary table and in the factsheet.
Environmental impacts	The assumption made to calculate the environmental impacts are stated as well as the references to the KBOB database [31]. The result for each component sub-type should be present in the factsheet.

Table 8. Ressource assessment reporting

4.3 Summary table

4.3.1 Discarded components

Following the on-site visit, the visual inspection and the damage assessment, component types with low reuse potential because of a damage class equal to D or E (bad condition or failure) are discarded. The discarded component types are described in a specific summary table containing the following information: component type name, damage class, dimensions, quantity (in m² or units), total area and volume, volume significance. Photos of the discarded components, illustrating the damages, are also included.

4.3.2 Selected components

All components that are further assessed are listed and inventoried in a summary table. Each component entered in this summary table has a factsheet containing all relevant and detailed information (see section 4.4). The following information should be provided: category, type number and name, damage class proportions, sub-types, dimensions, quantity (in m² or units), total area and volume, volume significance.

4.4 Components factsheets

For each selected component type, a detailed factsheet collects all relevant information:

- › plans and photos locating the component type in the building structure;
- › photos of the component;
- › detailed photos of the color and finishing of the component type;
- › plans with the main dimensions of the most common sub-type, including the cross-section;
- › description table with information about the construction year, the materials, the function and location, the accessibility, the connections, the color, the finishing, the overlays, etc.;
- › condition and durability table with the damage class proportions and other durability related information;
- › mechanical characteristics table with material properties;
- › inventory of the subtypes with their precise dimensions, cross-section resistance, quantity, volume significance, embodied environmental impact, etc.;
- › additional information and attention points.

A template of the factsheets is given in Annex B.

5 Conclusion

The present document describes a reusability assessment method and a resource assessment protocol for a soon-to-be deconstructed RC structure. It also describes the organization and content of the report and factsheets needed to summarize all information collected through the resource assessment protocol.

The reusability assessment of a RC component is based on the damage, the use and the intervention classes. It is a tool helping the designers evaluate the different reuse options for a component. The damage assessment is conducted before the deconstruction of the donor building and is a step of the resource assessment protocol. The use class – expressing the structural demand for the component – and the intervention class – describing maintenance and modifications on the component – depend on the design of the receiver building. Once the damage, use and intervention of a component have been classified, the reusability grade is obtained, expressing recommendation for the reuse and the related monitoring in the receiver structure. This reusability assessment method is intended to reduce the subjectivity of the assessment of reuse potential of RC components.

The resource assessment protocol presents the steps to gather quantitative and qualitative information on the stock of RC components available for reuse. By following this protocol, all technical information on a RC component type is collected and summarized in a factsheet which can later be used in the design of a receiver structure.

The methods and protocols described herein allow planning the deconstruction of an obsolete RC structure using methods that will subsequently facilitate the reuse of the components with the most potential. They also give the information for preliminary designs of a receiver structure. In later design stages, additional investigations on the stock might be required.

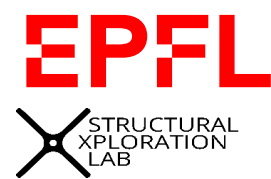
6 References

1. Bundesamt für Umwelt BAFU. Treibhausgasemissionen der Industrie [Internet]. 2022 [cited 2022 Oct 25]. Available from: <https://www.bafu.admin.ch/bafu/de/home/themen/klima/zustand/daten/treibhausgasinventar/industrie.html>
2. Wüest&Partner. Bauabfälle in der Schweiz - Hochbau. Studie 2015. Swiss Federal Office for the Environment (FOEN); 2015.
3. Knoeri C, Sanyé-Mengual E, Althaus HJ. Comparative LCA of recycled and conventional concrete for structural applications. *Int J Life Cycle Assess*. 2013 Jun 1;18(5):909–18.
4. Pellegrino C, Pipinato A, Modena C. A simplified management procedure for bridge network maintenance. *Structure and Infrastructure Engineering*. 2011;7(5):341.
5. Schellenberg K, Vogel T, Chèvre M, Alvarez M. Assessment of Bridges on the Swiss National Roads. *Structural Engineering International*. 2013 Nov 1;23(4):402–10.
6. Bertola NJ, Brühwiler E. Risk-based methodology to assess bridge condition based on visual inspection. *Structure and Infrastructure Engineering*. 2021 Aug 3;0(0):1–14.
7. Ellingwood BR. Risk-informed condition assessment of civil infrastructure: state of practice and research issues. *Structure and Infrastructure Engineering*. 2005 Mar 1;1(1):7–18.
8. Hallermann N, Morgenthal G. Visual inspection strategies for large bridges using Unmanned Aerial Vehicles (UAV). In 2014.
9. Seo J, Duque L, Wacker J. Drone-enabled bridge inspection methodology and application. *Automation in Construction*. 2018 Oct;94:112–26.
10. Falorca JF, Miraldes JPND, Lanzinha JCG. New trends in visual inspection of buildings and structures: Study for the use of drones. *Open Engineering*. 2021 May 18;11(1):734–43.
11. Omer M, Margetts L, Mosleh MH, Cunningham LS. Inspection of Concrete Bridge Structures: Case Study Comparing Conventional Techniques with a Virtual Reality Approach. *Journal of Bridge Engineering*. 2021 Oct 1;26(10):05021010.
12. Piras MV, Mistretta F, Fadda ML, Deias L. A Reliable Visual Inspection Method for Vulnerability Assessment of Hyperstatic Structures Using Fuzzy Logic Analysis. *Journal of Construction Engineering*. 2015 Aug 4;2015:e171989.
13. Campbell LE, Connor RJ, Whitehead JM, Washer GA. Human factors affecting visual inspection of fatigue cracking in steel bridges. *Structure and Infrastructure Engineering*. 2021 Nov 2;17(11):1447–58.
14. Bennetts J, Webb G, Denton S, Vardanega PJ, Loudon N. Quantifying Uncertainty in Visual Inspection Data. *Maintenance, Safety, Risk, Management and Life-Cycle Performance of Bridges*. 2018;2252.
15. ASTRA 62016. KUBA 5.1 - Guide pour les inspecteurs d'ouvrages d'art [Internet]. OFROU; 2021. Available from: https://www.astra.admin.ch/dam/astra/fr/dokumente/standards_fuer_nationalstrassen/kuba_51_leitfaden_fuer_inspektoren_von_kunstbauten.pdf.download.pdf/astra%2062016f.pdf
16. Gattulli V, Chiaramonte L. Condition Assessment by Visual Inspection for a Bridge Management System. *Computer-Aided Civil and Infrastructure Engineering*. 2005;20(2):95–107.
17. Roelfstra G, Hajdin R, Adey B, Brühwiler E. Condition Evolution in Bridge Management Systems and Corrosion-Induced Deterioration. *Journal of Bridge Engineering*. 2004 May 1;9(3):268–77.

18. Wai-Lok Lai W, Dérobert X, Annan P. A review of Ground Penetrating Radar application in civil engineering: A 30-year journey from Locating and Testing to Imaging and Diagnosis. *NDT & E International*. 2018 Jun 1;96:58–78.
19. SIA. Swiss Standard SIA 262:2013 - Concrete structures. SIA - Schweizerischer ingenieur und architektenverein; 2013.
20. SIA. Swiss Standard SIA 269:2011 - Existing structures - Basis. SIA - Schweizerischer ingenieur und architektenverein; 2011.
21. SIA. Swiss Standard SIA 269/8:2017 - Maintenance des structures porteuses - Séismes. SIA - Schweizerischer ingenieur und architektenverein; 2017.
22. FCRBE Interreg. A guide to inventory the reuse potential of construction products before demolition. 2020.
23. SIA. SIA 269/2 - Erhaltung von Tragwerken - Betonbau. SIA - Schweizerischer ingenieur- und architektenverein; 2011 p. 44.
24. Eidgenössische Materialprüfungs- und Forschungsanstalt EMPA, Hochschule für technik Rapperswil HSR. Stahl Datenbank [Internet]. [cited 2021 Nov 15]. Available from: <http://www.steeldata.ch/>
25. CEN. SN EN 12504-1 - Testing concrete in structures - Part 1: Cored specimens - Taking, examining and testing in compression. European Committee for Standardization; 2009.
26. CEN. SN EN 12390-13 - Testing hardened concrete - Part 13: Determination of secant modulus of elasticity in compression. European Committee for Standardization; 2013.
27. CEN. SN EN 14630 - Products and systems for the protection of concrete structures - Test methods - Determination of carbonation depth in hardened concrete by the phenolphthalein method. European Committee for Standardization; 2006.
28. CEN. SN EN 14629 - Products and systems for the protection and repair - Test methods - Determination of chloride content in hardened concrete. European Committee for Standardization; 2007.
29. Kumavat HR, Chandak NR, Patil IT. Factors influencing the performance of rebound hammer used for non-destructive testing of concrete members: A review. *Case Studies in Construction Materials*. 2021 Jun;14:e00491.
30. Crawford GI. Guide to nondestructive testing of concrete [Internet]. Federal Highway Administration; 1997. Report No.: HWA-SA-97-105. Available from: <https://rosap.nsl.bts.gov/view/dot/43757>
31. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren KBOB. Ökobilanzdaten im Baubereich 2009/1:2016 [Internet]. 2016 [cited 2021 Nov 3]. Available from: https://www.kbob.admin.ch/kbob/de/home/themen-leistungen/nachhaltiges-bauen/oekobilanzdaten_baubereich.html

Annex 1 – Checklist

Project name – Resource assessment for the reuse of load-bearing RC components



EPFL ENAC IA SXL
Smart living lab - HBL
Passage du Cardinal 13b
CH – 1700 Fribourg

Julie Devènes
Maléna Bastien-Masse
Corentin Fivet

julie.devenes@epfl.ch
malena.bastien-masse@epfl.ch
corentin.fivet@epfl.ch
sxl.epfl.ch

date
Version 1.0

Checklist - Report author's name

Description:

1. Introduction

Check

○ General information on the report

- Appropriate title
- Goal of the report
- Out of scope elements

KO
KO
KO

○ General information on the building

- Building situation
- Date of construction
- Building structural system
- Materials
- Building use
- Deconstruction reasons

KO
KO
KO
KO
KO
KO

Comments:

2.1 Review of existing data

All relevant information found in the existing documentation should be summarized in the report.

○ Existing blueprints

- Formwork plans from the construction period
- Steel reinforcement plans from the construction period

KO
KO

▪ Any other existing plans	KO
○ Pollutant diagnosis report	
▪ Presence of toxic substances in the concrete components	KO
▪ Presence of toxic substances in the joint between concrete components	KO
▪ Presence of toxic substances in the non-structural building components	KO
○ Any other existing documents	KO

Comments:

2.2 Classification of components

A figure showing the location of element types should be included. All categories, types and subtypes of components should be described and presented in a summary table

KO

○ Component categories	
▪ Identify the main categories of components	KO
○ Component types	
▪ For each category, identify types that present similar characteristics.	KO
○ Components subtypes	
▪ For each type, group by subtype with same geometries.	KO

Comments:

2.3 On-site visits and visual inspection

The date(s) of the visit and the name(s) of the person(s) present should be mentioned in the report. A brief description of the visit, observations and work carried out is to be included in the report.

KO

○ Investigations	
▪ Define destructive investigation positions	KO
▪ Perform non-destructive investigations	KO
○ Visual inspection	
▪ Determine component conditions	KO
▪ Identify components to discard	KO
▪ Determine the color and finishing of the components	KO

- Data collection
 - Collect any missing information (dimensions, overlay, etc.)
 - Take sufficient photos of each component type

KO
KO

Comments:

2.4 Investigations on materials

- Destructive investigations

The location of the samples should be illustrated on a plan view of the assessed building. All results of the tests should be clearly given in the report.

KO

- Steel rebars
- Openings in the cover concrete to verify rebar layout
 - Tension tests on sampled steel rebars

KO
KO

- Concrete
- Density
 - Carbonation depth
 - Compressive strength testing
 - Young modulus testing
 - Other required testing (e.g. Alkali-silica reaction, chlorides content)

KO
KO
KO
KO
KO

- Non-destructive investigations (optional)

The location of the tests must be described or illustrated on a plan view. All results should be given and interpreted in the report.

KO

Comments:

2.5 Assessment of components

- Grading of the condition state
- Aesthetics
 - Match component type color with RAL chart
 - Define the concrete finishing
- Accessibility
 - Define the accessibility of each type of component
- Cross-section resistance
 - Define the rebar present in the concrete components
 - Calculation of the cross-section resistance

KO

KO
KO

KO

KO
KO

<ul style="list-style-type: none">○ Durability<ul style="list-style-type: none">▪ Carbonation depth compared to the rebar covering	KO
<ul style="list-style-type: none">○ Significance<ul style="list-style-type: none">▪ Calculation of the component subtype significance	KO
<ul style="list-style-type: none">○ Environment impact<ul style="list-style-type: none">▪ Estimation of the embodied global warming potential of the component subtype	KO

Comments:

2.6 Summary table

<ul style="list-style-type: none">○ Discarded components<ul style="list-style-type: none">▪ Selection of photos▪ Summary table	KO KO
<ul style="list-style-type: none">○ Selected components<ul style="list-style-type: none">▪ Name▪ Condition▪ Description▪ Dimension▪ Quantity▪ Area▪ Volume▪ Significance▪ Summary table	KO KO KO KO KO KO KO KO

Comments:

2.7 Component factsheets

All field in the factsheet should be completed.	KO
<ul style="list-style-type: none">○ For each component type<ul style="list-style-type: none">▪ Plan and photo location of the element type▪ Photo of the component type▪ Detailed photos of the color and finishing of the type▪ Plans with the main dimensions of the most common sub-type	KO KO KO KO

- Description (exposition, initial function, location, etc.)
- Information on condition and durability
- Information on the mechanical characteristics
- Inventory (dimensions, cross-section resistance, quantity, significance, etc.)
- Additional information

KO
KO
KO
KO
KO

Comments:

Conclusion:

Annex 2 – Factsheet templates

Type :	Type number	Category :	Category name
Name			

Location

Figure

Type name

General photos

Color and finishing

Close-up photos

Connections

Figures and close-up photos

Type : Type number

Category : Category name

Name

Subtype n° , dimensions

1:

Figure

Subtype n° , cross-section

1:

Figure

Type : Type number

Category : Category name

Name

Description

Construction year	
Material	
Actual location	
Initial function	
Accessibility	
Anchor points	
Exposition	
Color	
Finishing	
Overlays	Type Fixation Thickness
Connection type	
Deconstruction tool	

Condition and durability

Damage class	
Carbonation depth [mm]	
Toxic substance	

Mechanical characteristics

Concrete density (ρ_c)	
Concrete compressive strength (f_{ck})	
Concrete young modulus (E_{cm})	
Reinforcement tensile strength (f_{sk})	
Reinforcement young modulus (E_s)	

Component	Geometry			Inventory				Environmental impacts			
Subtype	Dimensions (W x L x T) [mm]	Reinforcement [mm]	Cross-section resistance [kNm]	Quantity [u]	Weight [kg/u]	Total area [m²]	Total volume [m³]	Significance	Initial production Conventional demolition [kgCO2-eq/u]	Initial production Conventional demolition [kWh oil-eq/u]	

Additional information

Additional note	
Attention point	