De la démolition à la reconstruction : Techniques pour le réemploi du béton

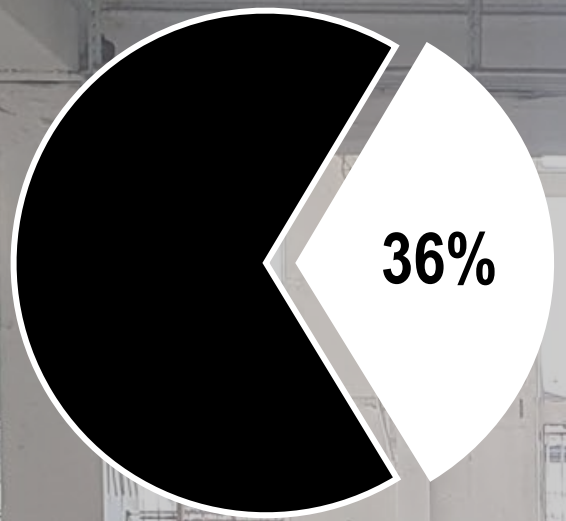


Maléna Bastien Masse, Dr ès Sc. EPFL
Ingénieure civile et chercheuse

EPFL STRUCTURAL XPLORATION LAB

12 novembre 2024

béton



36% **des déchets de construction & démolition**

Projekt MatCH – Bau
Empa, BAFU, 2016

© Bastien-Masse, EPFL, 2023

au-delà du béton d'aggrégats recyclés

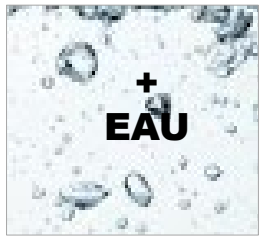
RECYCLAGE















≠

REEMPLOI







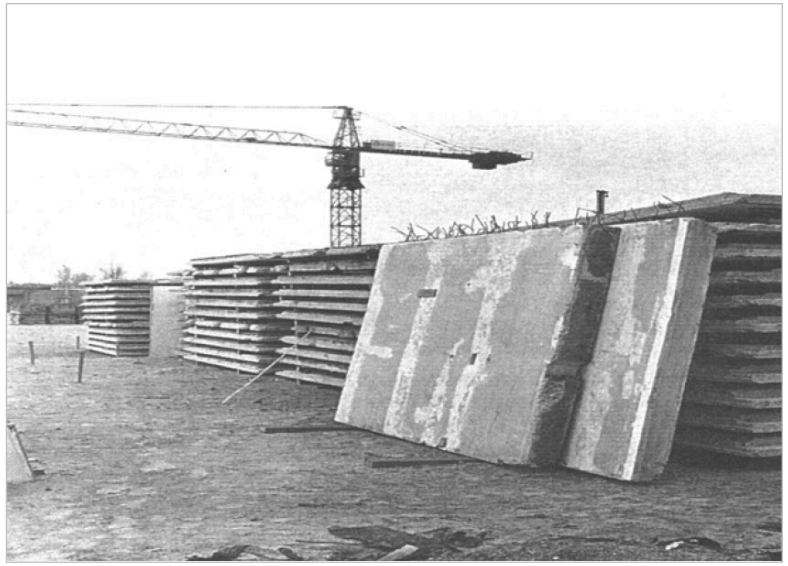
plus de 50 exemples



réemploi d'éléments préfabriqués









Bâtiment de logement

(Middelburg, NL, 1984-1986)

Réemploi de panneaux préfabriqués (murs et dalles) pour la reconstruction de bâtiments de 3 et 4 étages

Naber, 2012; Kristinsson et al. 2001; te Dorsthorst et al. 2000; Huuhka et al. 2019

réemploi d’éléments en béton coulé sur place



© Küpfer, EPFL, 2023

réemploi d'éléments en béton coulé sur place

FAZ Architectes
pavage
(Meyrin, CH, 2022)





Baubüro in situ
fondation de colonne
(Zürich, CH, 2022)

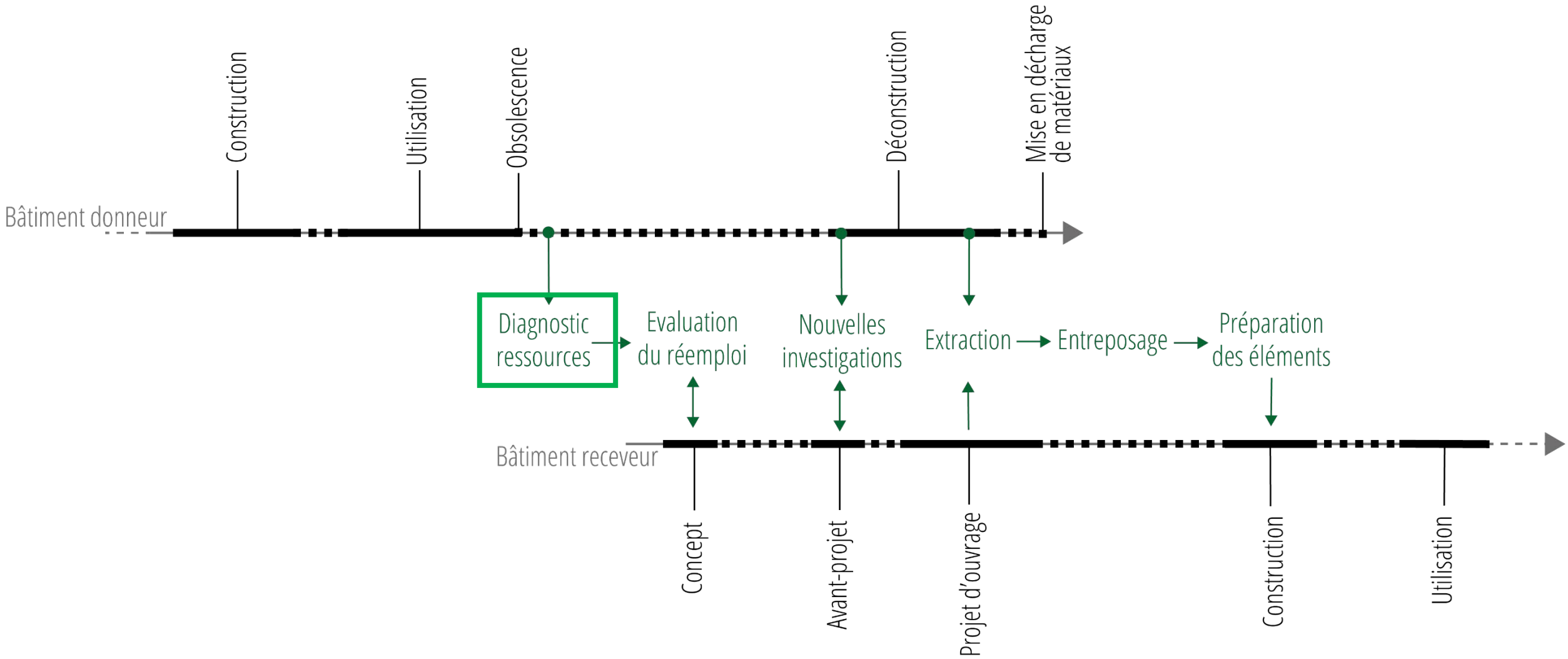
2401 and HEIA
paroi berlinoise
(Renens, CH, 2023)





Superlocal
pavillons
(Kerkrade, NL, 2018)

nouvelles phases de projet



données existantes

- Plans
  - architecte ✓
  - coffrage & armature ✗
- Propriétés des matériaux ✗
- Reports ✓



Construction of Triemli Personnalhäuser, Zürich, 1964 © Baugeschichtliches Archiv (BAZ) Stadt Zürich, Köhli Ernst

inventaire

Precast RC

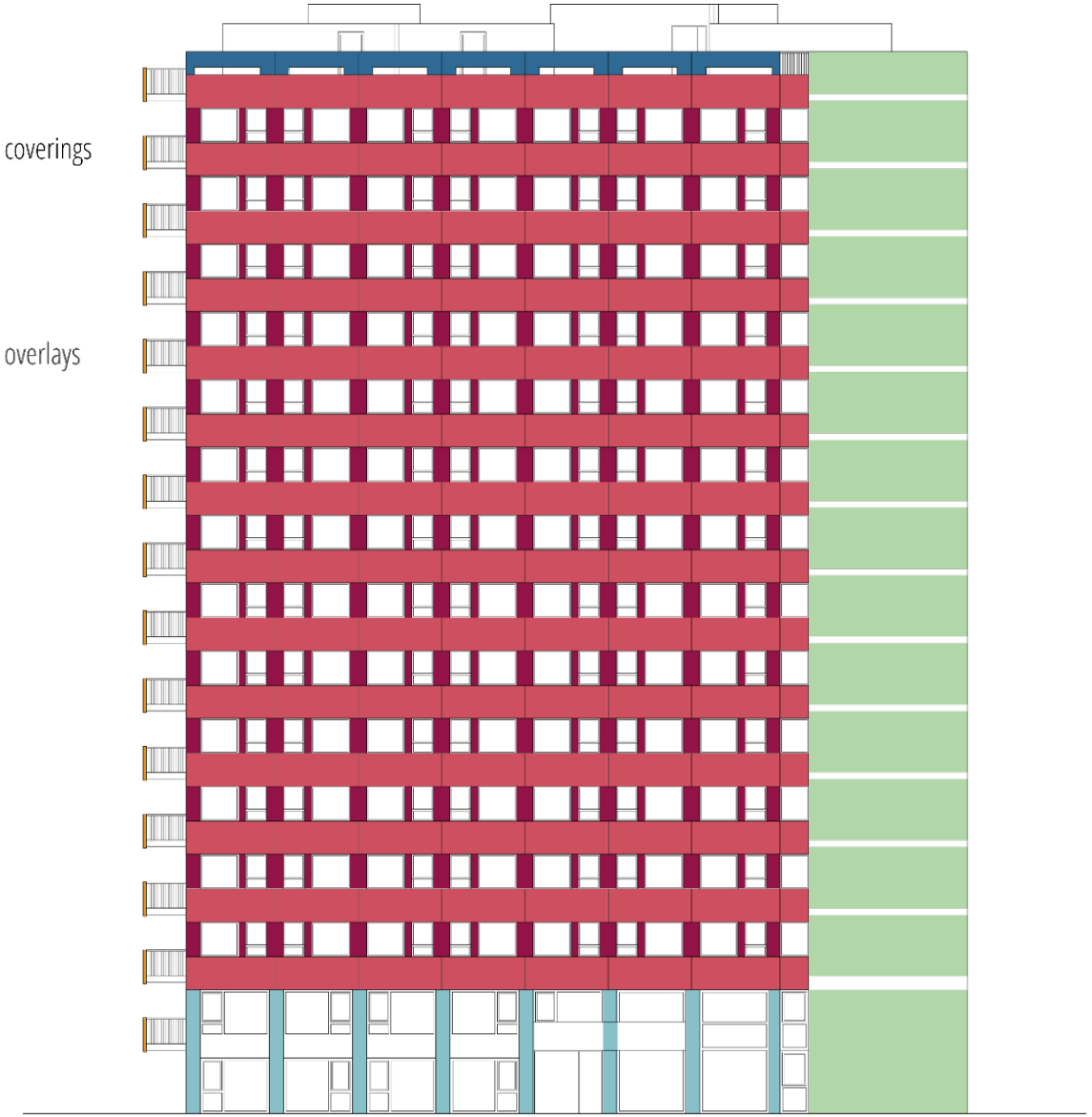
- 01 - Balcony railings
- 02 - Ground- and 1st-floor column coverings
- 03 - Window apron walls
- 04 - Walls between windows
- 06 - Attic walls
- 08 - Prelam slabs with cast-in-place overlays

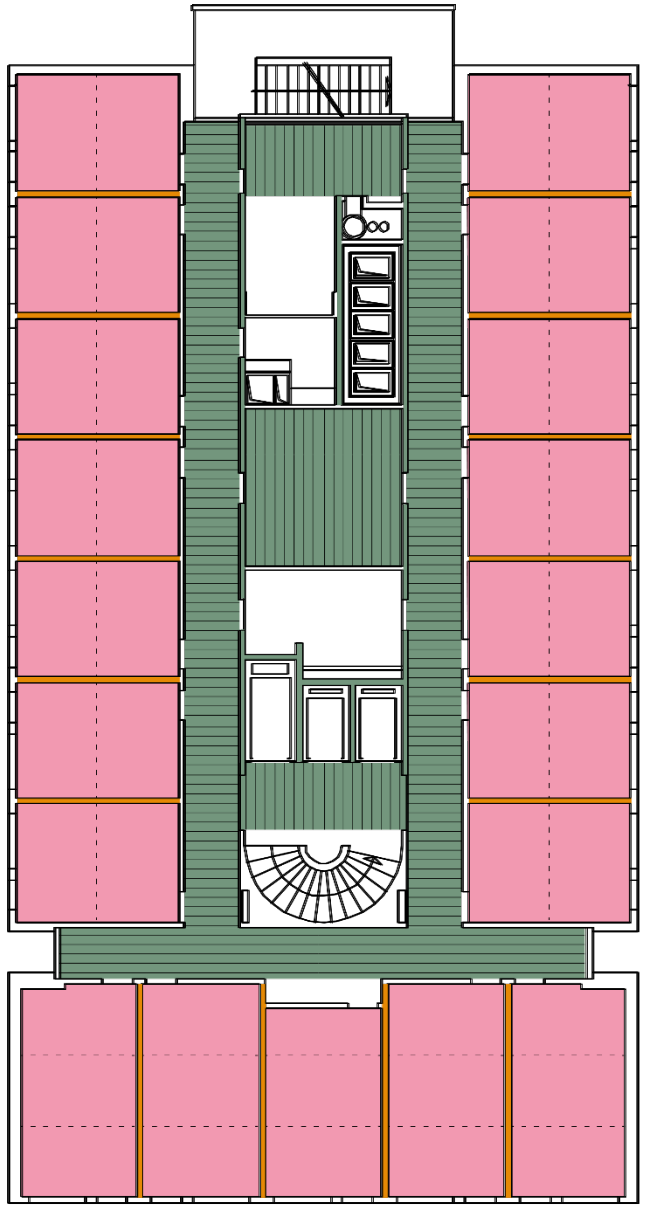
Cast-in-place RC

- 07 - Cast-in-place facade walls
- 09 - Cast-in-place slabs
- 11 - Cast-in-place interior walls

Precast masonry

- 10 - Preton walls 15 cm





© SXL, EPFL, 2022

investigations

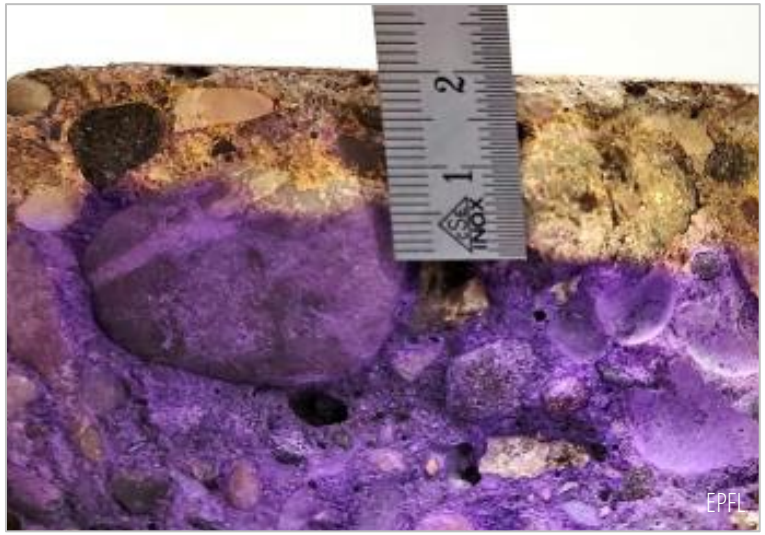
non-destructif

destructif

inspection visuelle



carbonatation



géo-radar



disposition armature



scléromètre

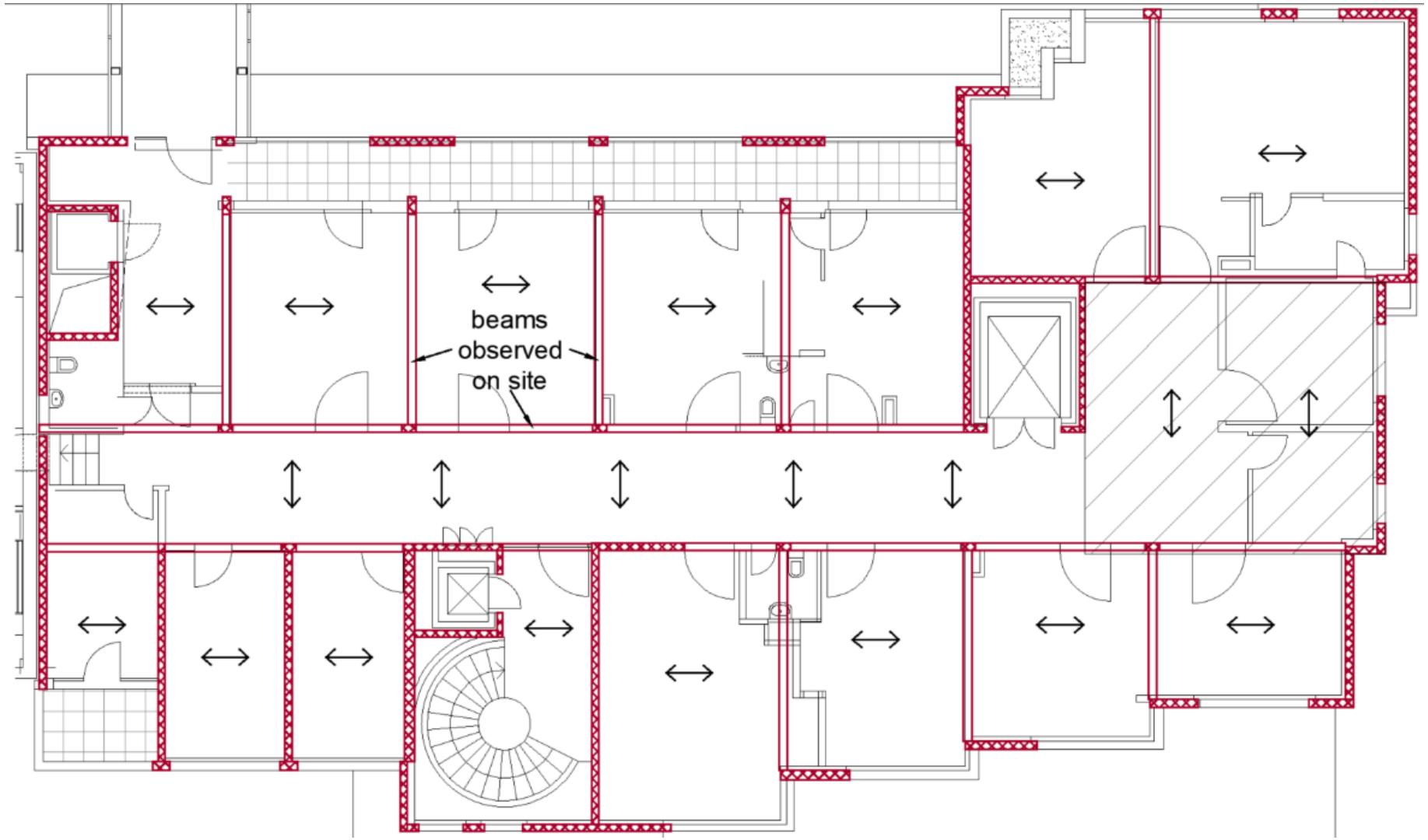


propriétés mécaniques

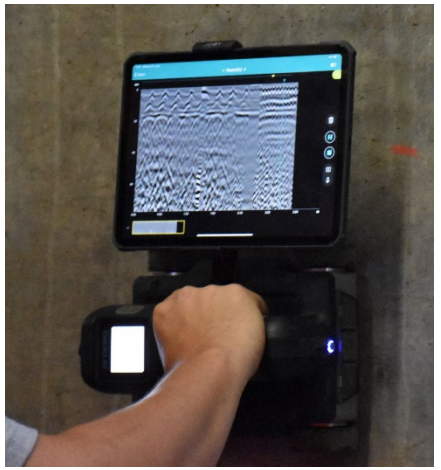


Devènes et al. · Reusability assessment of reinforced concrete components prior to deconstruction from obsolete buildings · 2023, tbp

analyse de la structure





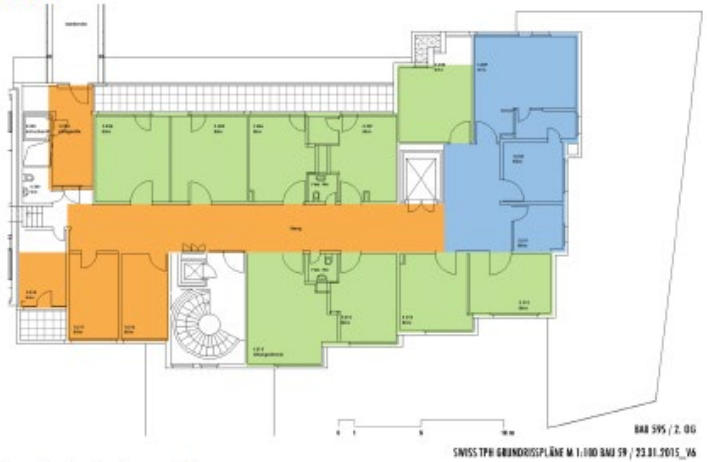


fiches d'information

Type SOC5903 — Category: Slab components

Cast-in-place slabs

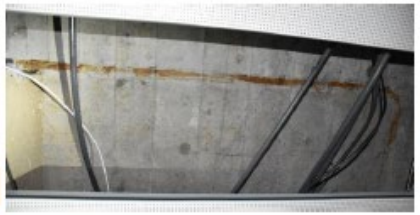
Location



Location plan for the second floor.

Photos





Overlays





Floor surface coating





Suspended or acoustic ceiling type

Type SOC5903 — Category: Slab components

Cast-in-place slabs

Description

Construction year	1965
Material	Cast-in-place reinforced concrete
Actual location	All floors
Initial function	Slab load-bearing component
Accessibility	Difficult – 3 & more component to dismantle before
Anchor points	None
Exposition	Inside, not exposed
Color	Shade of grey

Finishing	Type	Fixation	Thickness
Overlays			
Upper surface	Multiple color linoleum	Unknown	Unknown
	Cement screed		9.0 - 10.5 cm
	Coconut wool		1.0 – 1.4 cm
Lower surface	Metal suspended ceiling or plaster acoustic ceiling		Unknown

Connexion type	Monolithic connexion with facades, walls and columns
Deconstruction tool	Diamond saw or hydro-blasting

Condition and durability

Damage assessment	100 % good
Carbonatation depth [mm]	n.a
Toxic substance	Asbestos*, PCB**

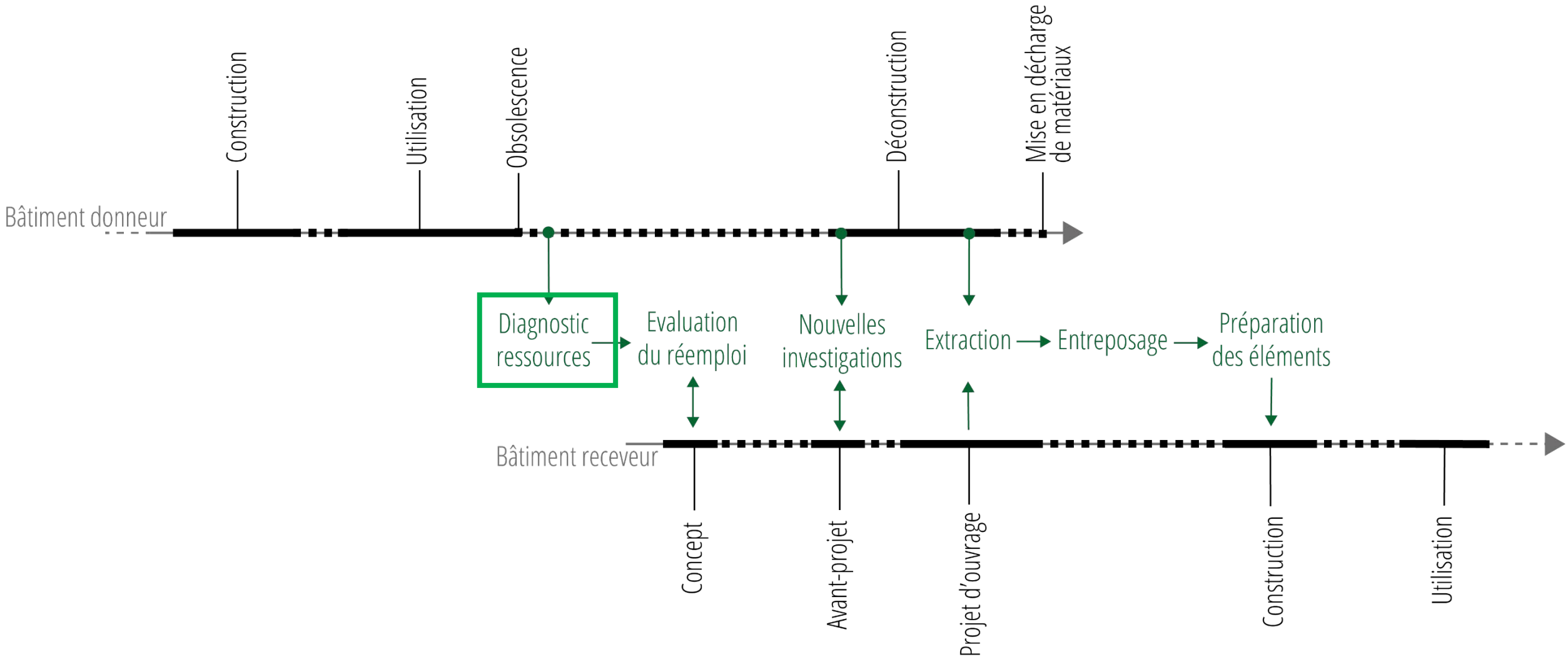
Mechanical characteristics

Concrete density (ρ_c)	2350 kg/m³
Concrete compressive strength (f_{cd})	37 MPa
Concrete young modulus (E_{cm})	36.2 GPa
Reinforcement tensile strength (f_{sd})	300 MPa
Reinforcement young modulus (E_s)	n.a

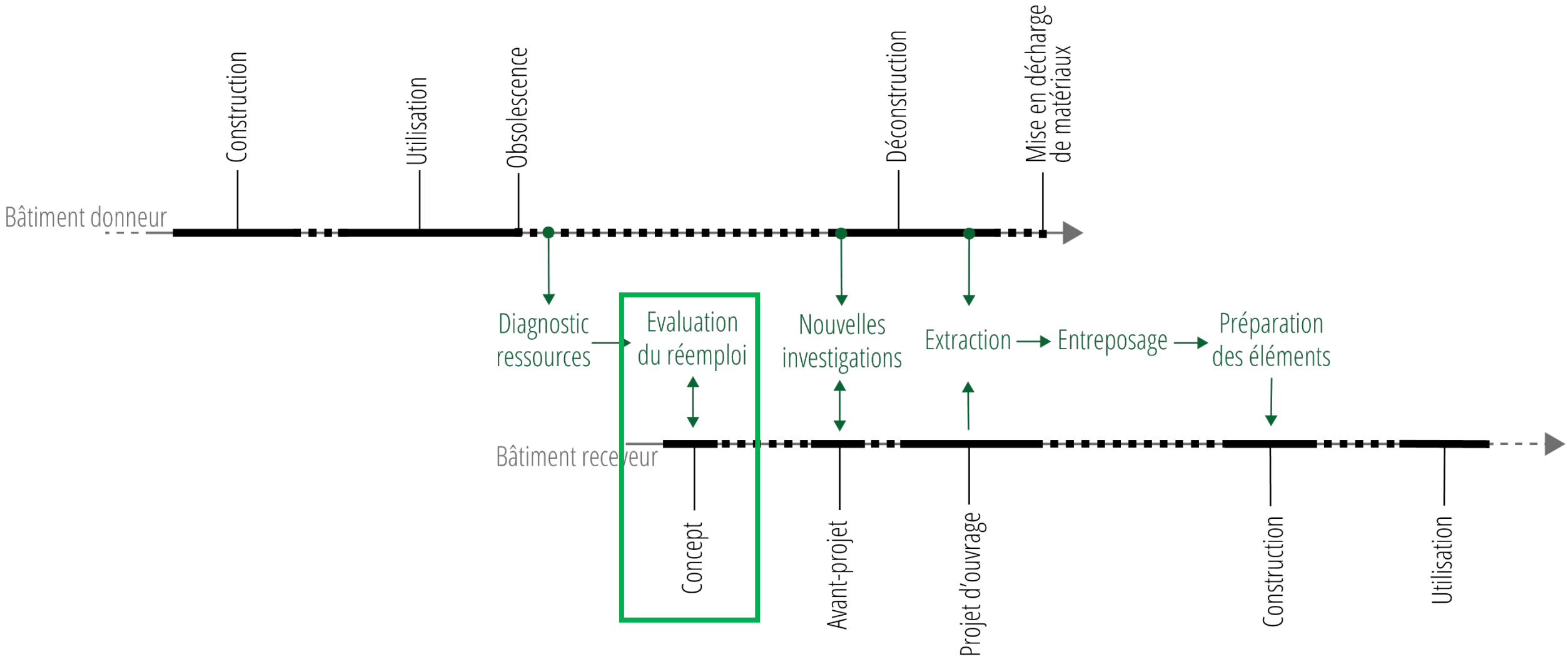
Component	Geometry			Inventory				Environmental impacts			
Subtype	Dimensions (T) [mm]	Reinforcement [mm] ***	Cross-section resistance [kNm] ***	Quantity [m²]	Weight [kg/ m²]	Total volume [m³]	Volume significance	Initial production [kgCO2-eq/ m²]	Conventional demolition [kgCO2-eq/ m²]	Initial production [kWh oil-eq/ m²]	Conventional demolition [kWh oil-eq/ m²]
Orange area L=2.9 m	160	Mid-span: L: Ø10; s = 150 T: Ø8; s = 150	Mid-span: L: 20.0 T: 12.0	506	400	81	12.1 %	36	52	49	20.8
Green area L=4.6 m	160	Mid-span: L: Ø10; s = 150 T: Ø8; s = 150	Mid-span: L: 20.0 T: 12.0	916	400	147	21.9 %	36	52	49	20.8
Blue area L = 6.5 m	160	Mid-span: L: Ø10; s = 150 T: Ø8; s = 150	Mid-span: L: 20.0 T: 12.0	358	400	57	8.56 %	36	52	49	20.8
Others L = var.	160	Mid-span: L: Ø10; s = 150 T: Ø8; s = 150	Mid-span: L: 20.0 T: 12.0	750	400	120	17.9 %	36	52	49	20.8

L: longitudinal and T: transversal directions

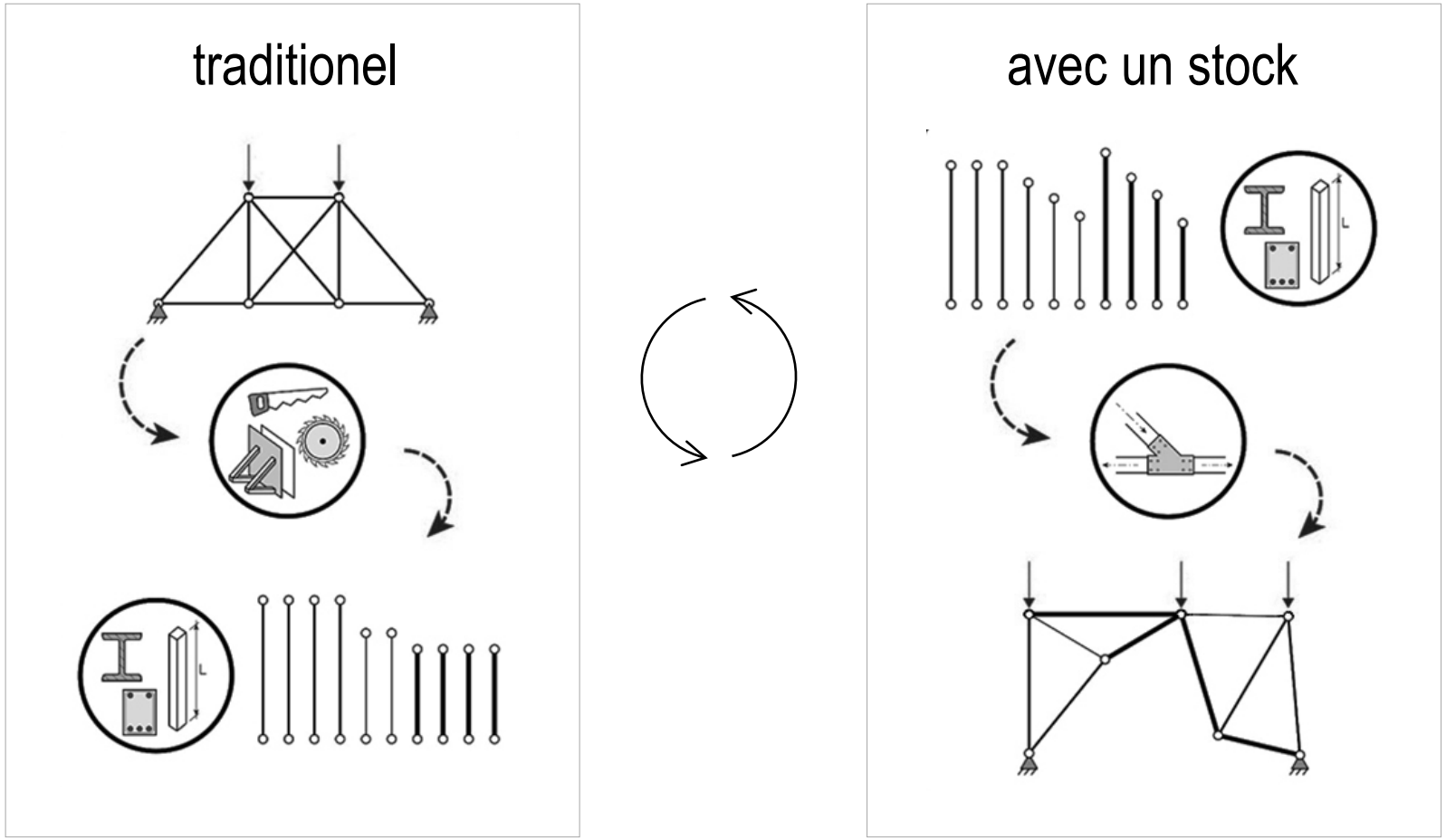
nouvelles phases de projet



nouvelles phases de projet



nouvelles méthodes de conception



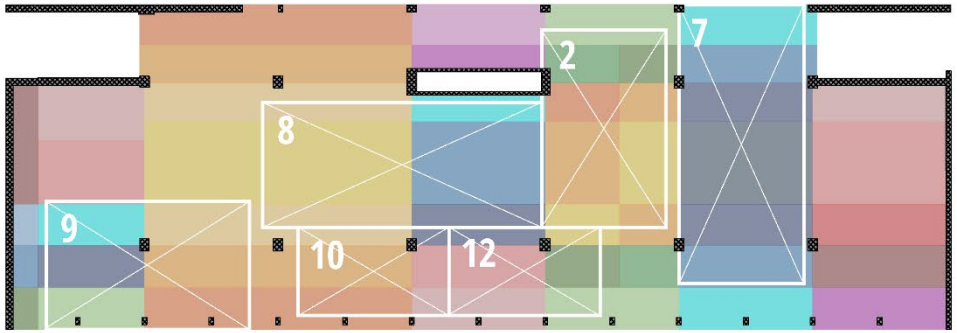
conception avec le stock

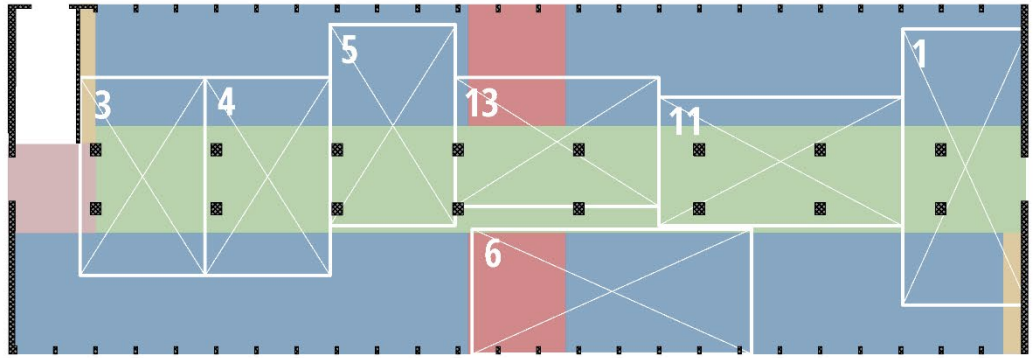
Bâtiments donneurs



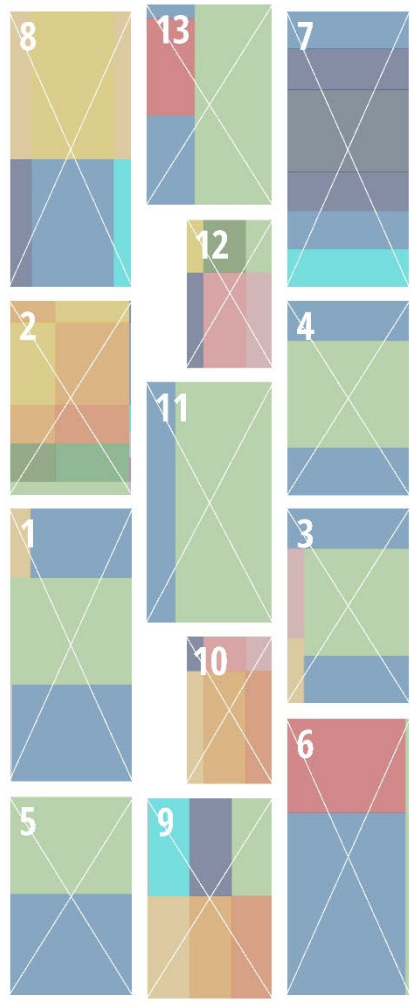


Plans de sciage

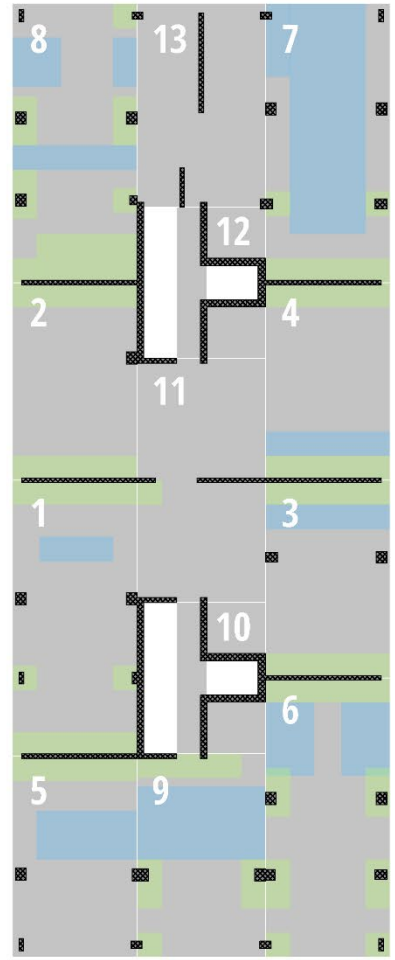




Reassemblage



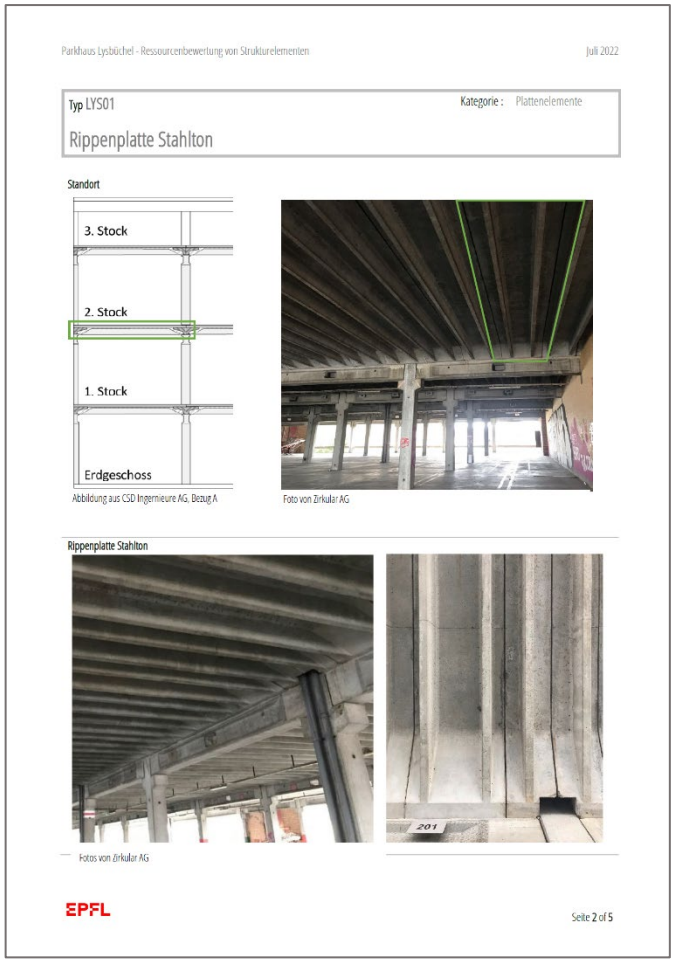
Renforcement



-75% de CO2eq par rapport à une nouvelle dalle en béton!

Widmer et al. · Design of building structures with reused slabs and walls saw cut from obsolete cast-in-place reinforced concrete components · 2023, tbp

Parkhaus Lysbüchel, Basel



Parkhaus Lysbüchel - Ressourcenbewertung von Strukturelementen Juli 2022

Typ LYS01 Kategorie : Plattenelemente

Rippenplatte Stahlton

Standort

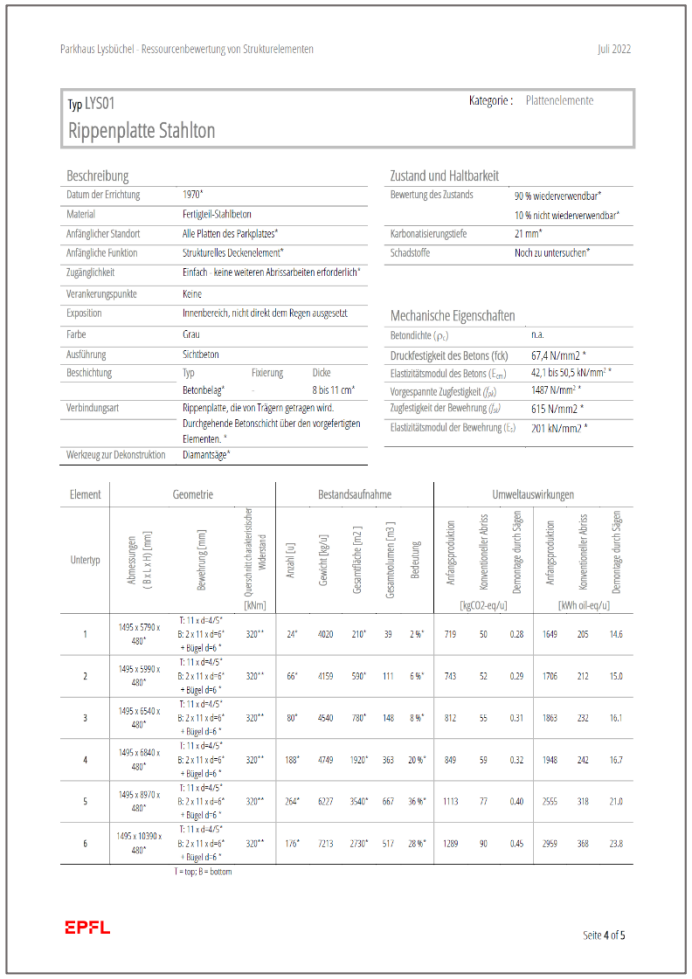
Abbildung aus CSD Ingenieure AG, Bezug A

Foto von Zirkular AG

Rippenplatte Stahlton

Fotos von Zirkular AG

EPFL Seite 2 of 5



Parkhaus Lysbüchel - Ressourcenbewertung von Strukturelementen Juli 2022

Typ LYS01 Kategorie : Plattenelemente

Rippenplatte Stahlton

Beschreibung

Datum der Errichtung	1970*		
Material	Fertigteil-Stahlbeton		
Anfänglicher Standort	Alle Platten des Parkplatzes*		
Anfängliche Funktion	Strukturelles Deckenelement*		
Zugänglichkeit	Einfach - keine weiteren Abrissarbeiten erforderlich*		
Verankerungspunkte	Keine		
Exposition	Innenbereich, nicht direkt dem Regen ausgesetzt		
Farbe	Grau		
Ausführung	Sichtbeton		
Beschichtung	Typ	Fixierung	Dicke
	Betonbelag*	-	8 bis 11 cm*
Verbindungsart	Rippenplatte, die von Trägern getragen wird. Durchgehende Betonschicht über den vorgefertigten Elementen. *		
Werkzeug zur Dekonstruktion	Diamantsäge*		

Zustand und Haltbarkeit

Bewertung des Zustands	90 % wiederverwendbar*
	10 % nicht wiederverwendbar*
Karbonatisierungstiefe	21 mm*
Schadstoffe	Noch zu untersuchen*

Mechanische Eigenschaften

Betondichte (ρ_c)	n.a.
Druckfestigkeit des Betons (fck)	67,4 N/mm2 *
Elastizitätsmodul des Betons (E_{cm})	42,1 bis 50,5 kN/mm² *
Vorgespannte Zugfestigkeit (f_{pk})	1487 N/mm² *
Zugfestigkeit der Bewehrung (f_{sk})	615 N/mm2 *
Elastizitätsmodul der Bewehrung (E_s)	701 kN/mm2 *

Element	Geometrie			Bestandsaufnahme					Umweltauswirkungen					
Untertyp	Abmessungen (B x L x H) [mm]	Bewehrung [mm]	Querschnittlich charakteristischer Widerstand [kNm]	Anzahl [u]	Gewicht [kg/u]	Gesamtfläche [m2]	Gesamtvolumen [m3]	Beifestigung	Anfangsproduktion	Konventioneller Abriss	Demontage durch Sägen	Anfangsproduktion	Konventioneller Abriss	Demontage durch Sägen
									[kgCO2-eq/u]			[MWh oil-eq/u]		
1	1495 x 5790 x 480*	T: 11 x d=4/5* B: 2 x 11 x d=6* + Bügel d=6 *	320**	24*	4020	210*	39	2 %*	719	50	0.28	1649	205	14.6
2	1495 x 5990 x 480*	T: 11 x d=4/5* B: 2 x 11 x d=6* + Bügel d=6 *	320**	66*	4159	590*	111	6 %*	743	52	0.29	1706	212	15.0
3	1495 x 6540 x 480*	T: 11 x d=4/5* B: 2 x 11 x d=6* + Bügel d=6 *	320**	80*	4540	790*	148	8 %*	812	55	0.31	1863	232	16.1
4	1495 x 6840 x 480*	T: 11 x d=4/5* B: 2 x 11 x d=6* + Bügel d=6 *	320**	188*	4749	1920*	363	20 %*	849	59	0.32	1948	242	16.7
5	1495 x 8970 x 480*	T: 11 x d=4/5* B: 2 x 11 x d=6* + Bügel d=6 *	320**	264*	6227	3540*	667	36 %*	1113	77	0.40	2555	318	21.8
6	1495 x 10390 x 480*	T: 11 x d=4/5* B: 2 x 11 x d=6* + Bügel d=6 *	320**	176*	7213	2730*	517	28 %*	1289	90	0.45	2959	368	23.8

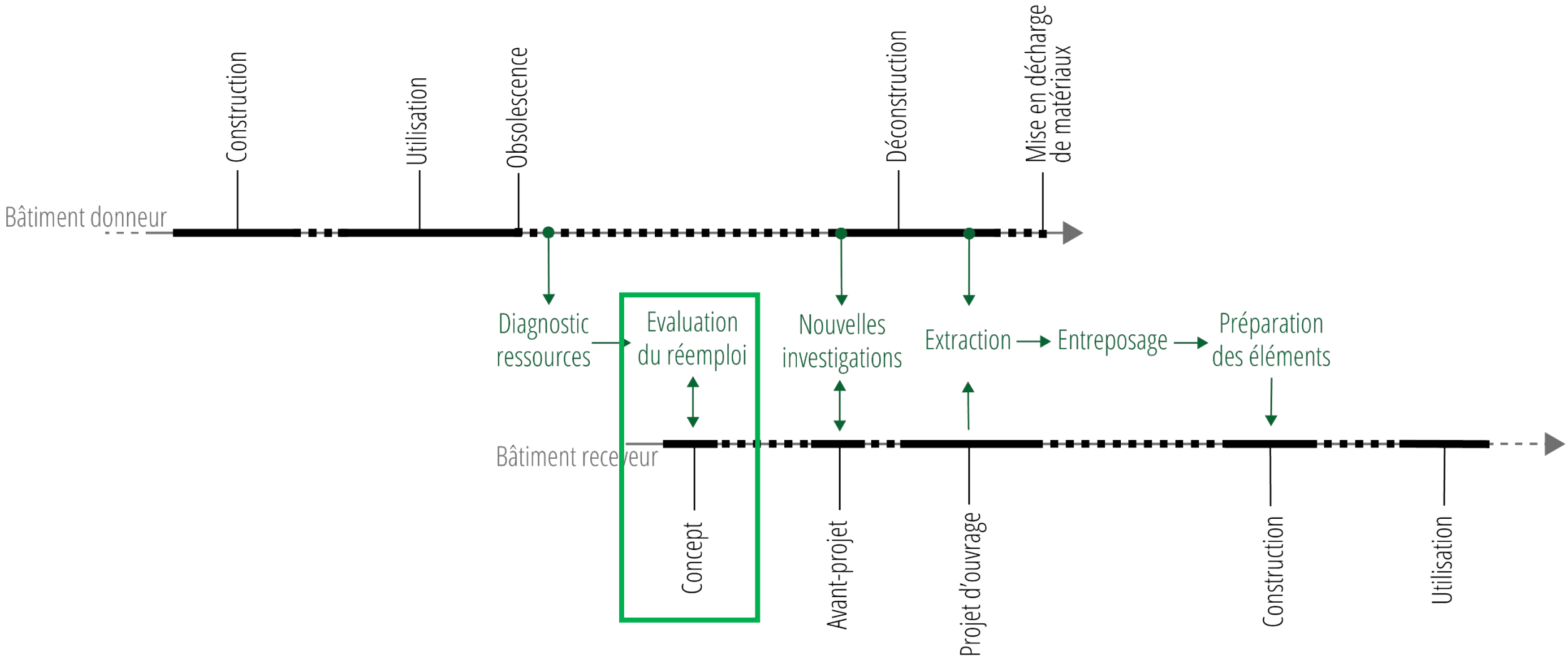
T = top; B = bottom

EPFL Seite 4 of 5

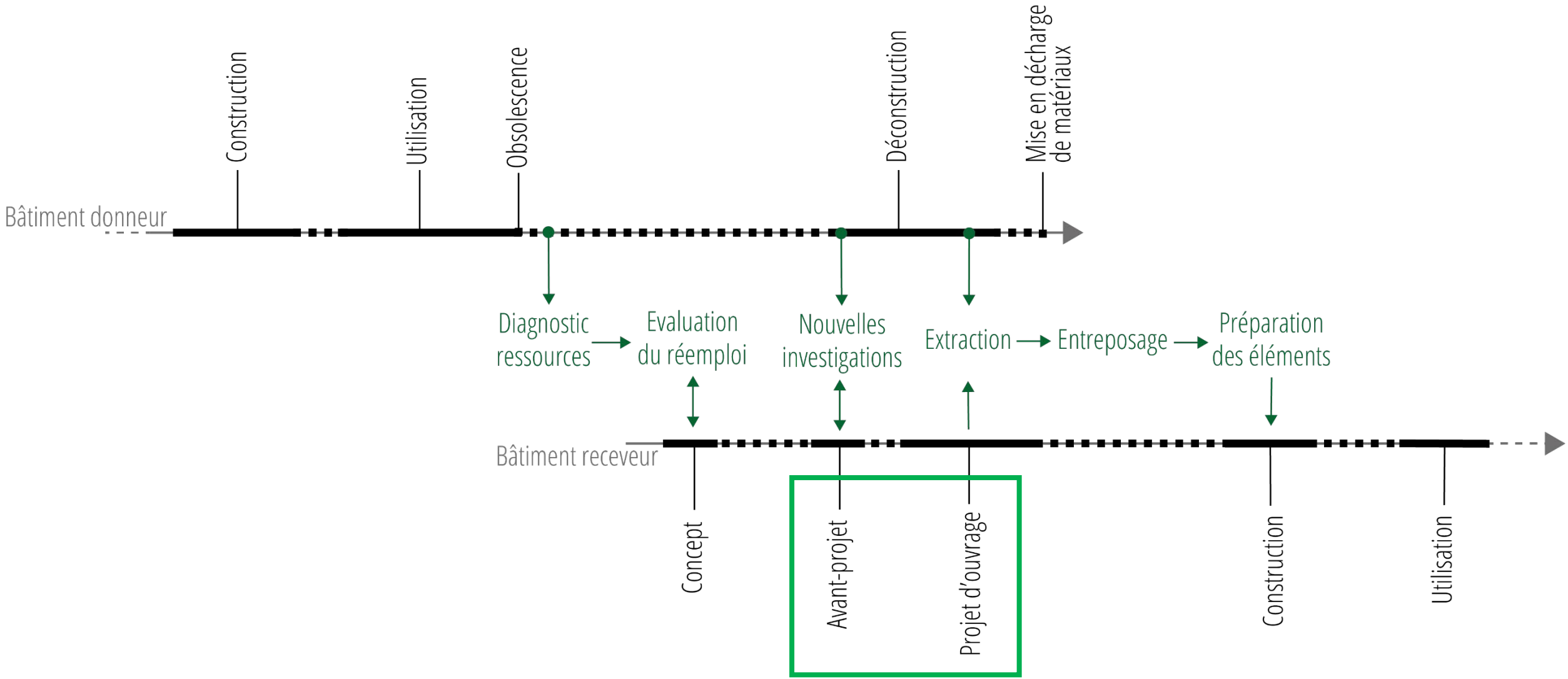


© Parabase, 2023

nouvelles phases de projet

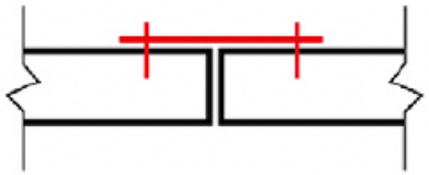


nouvelles phases de projet

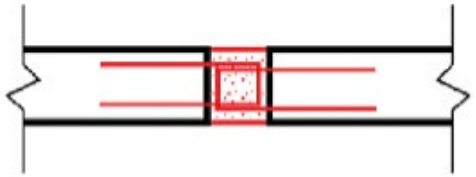


nouvelles connections

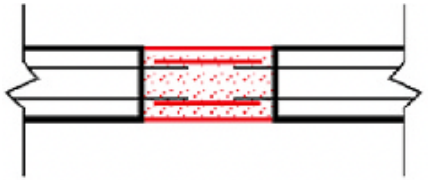
plaques d'acier avec ancrages



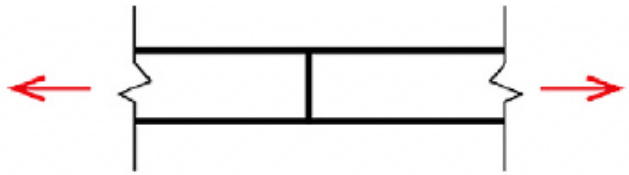
nouvelles barres scellées



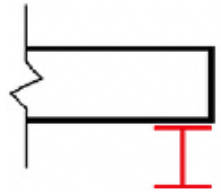
nouvelles barres soudées



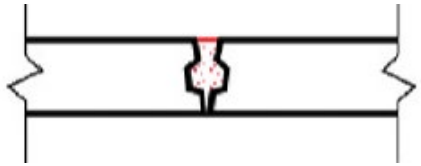
post-contrainte



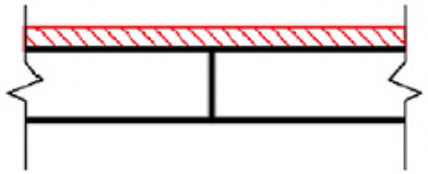
poutres additionelles



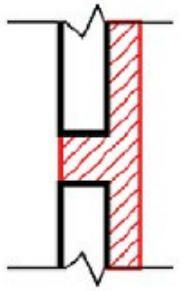
clé de cisaillement longitudinale avec mortier



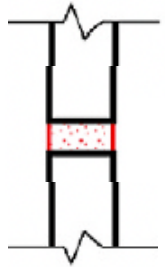
nouvelle couche de béton



matrice de béton



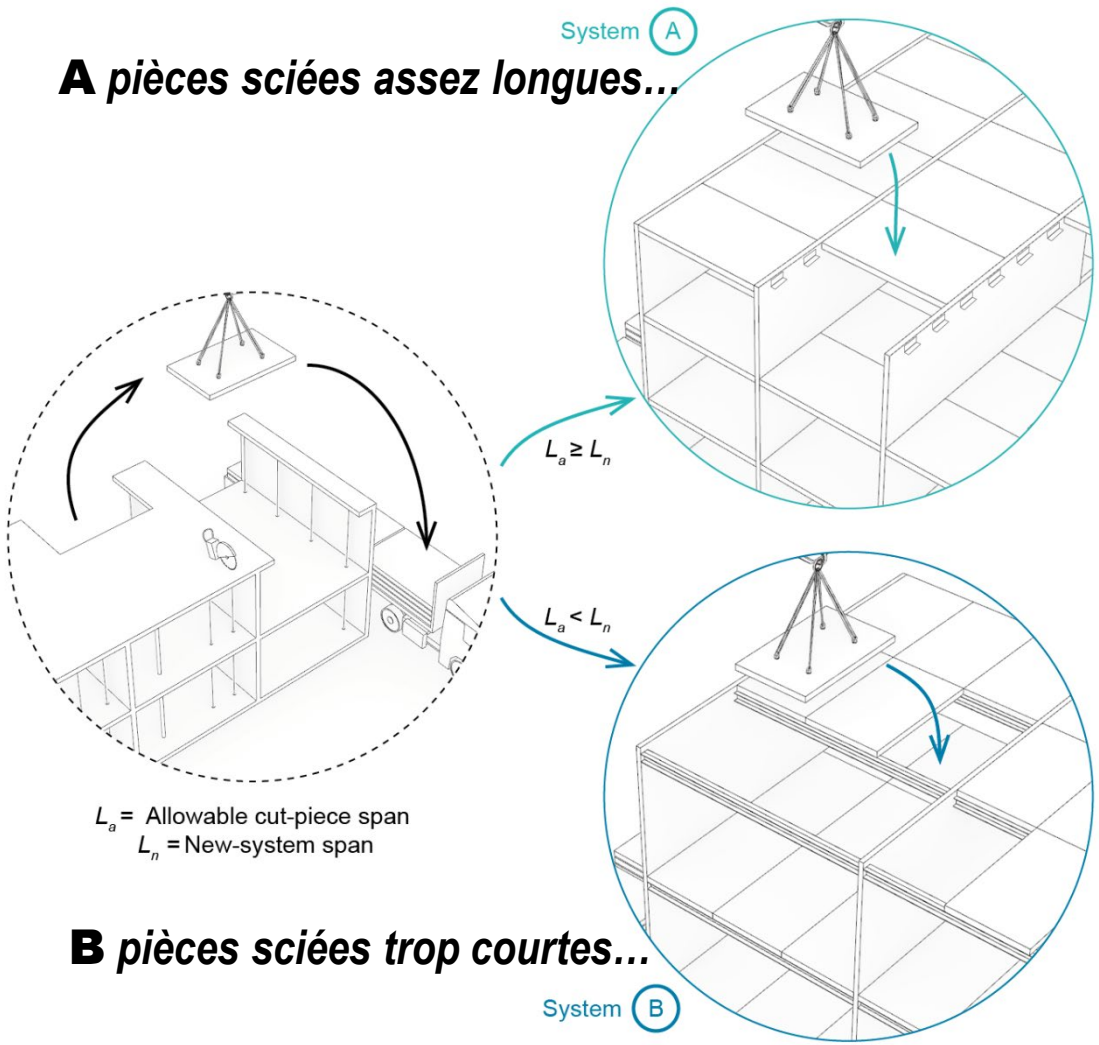
mortier entre les éléments

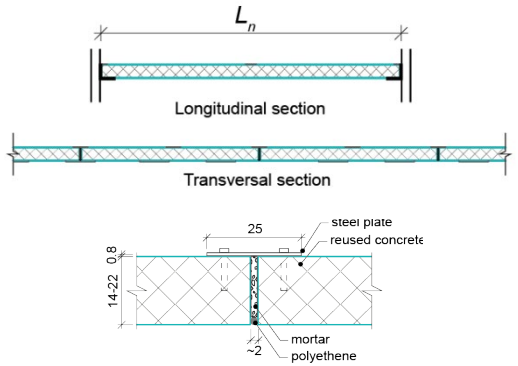


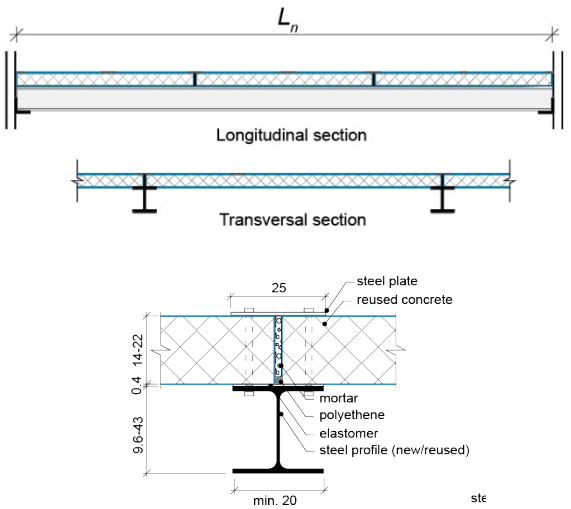
nouveau système de dalles

nouvelle structure

structure donneuse







A

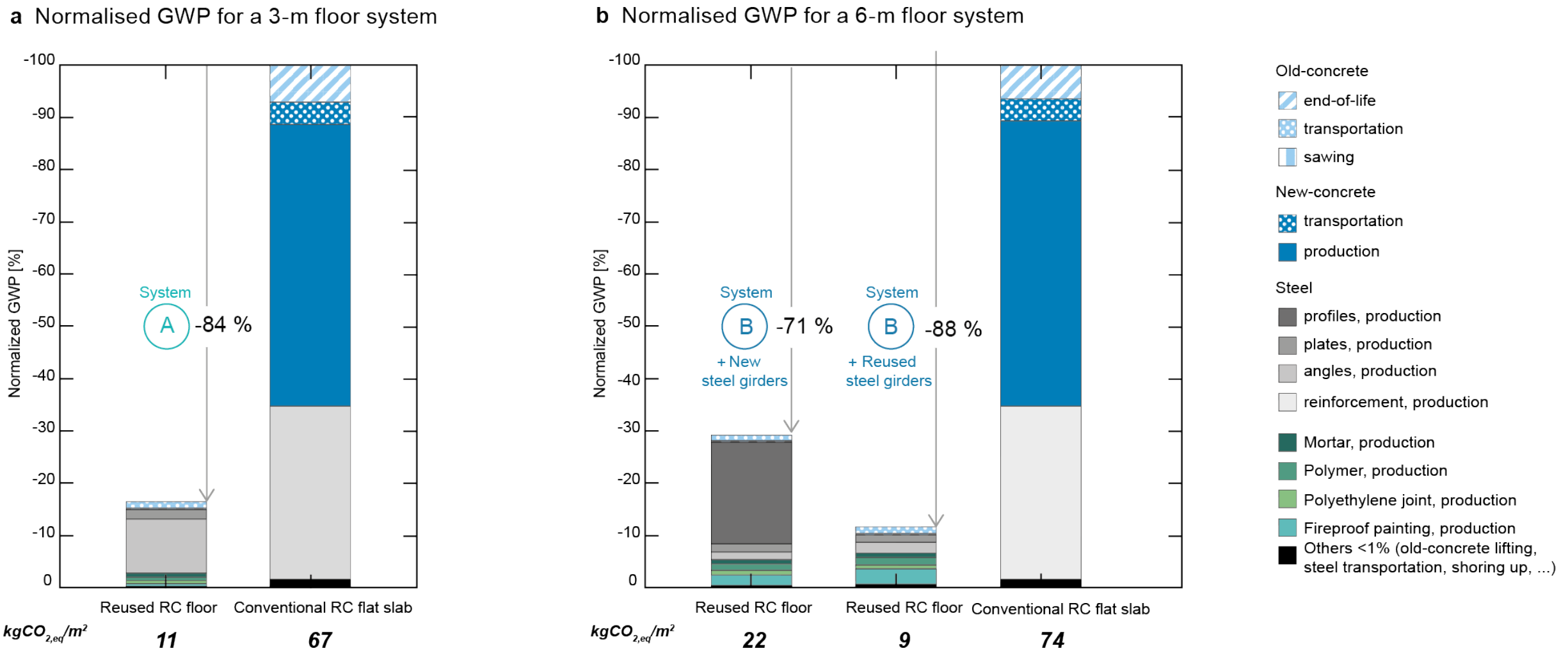


B

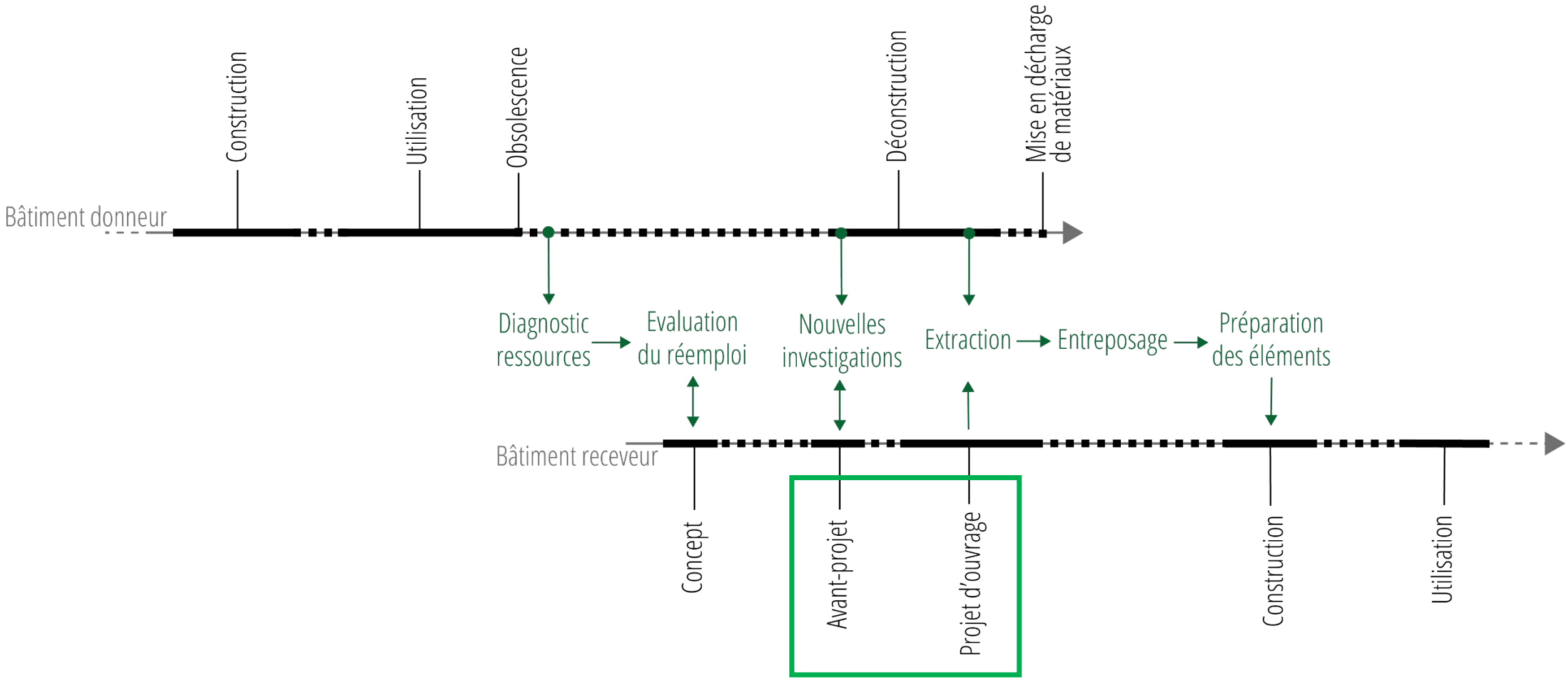


Küpfer et al. · Design of New Low-Carbon Floor Systems by Reusing Cut Cast-in-Place Concrete Pieces. · 2023 | 22

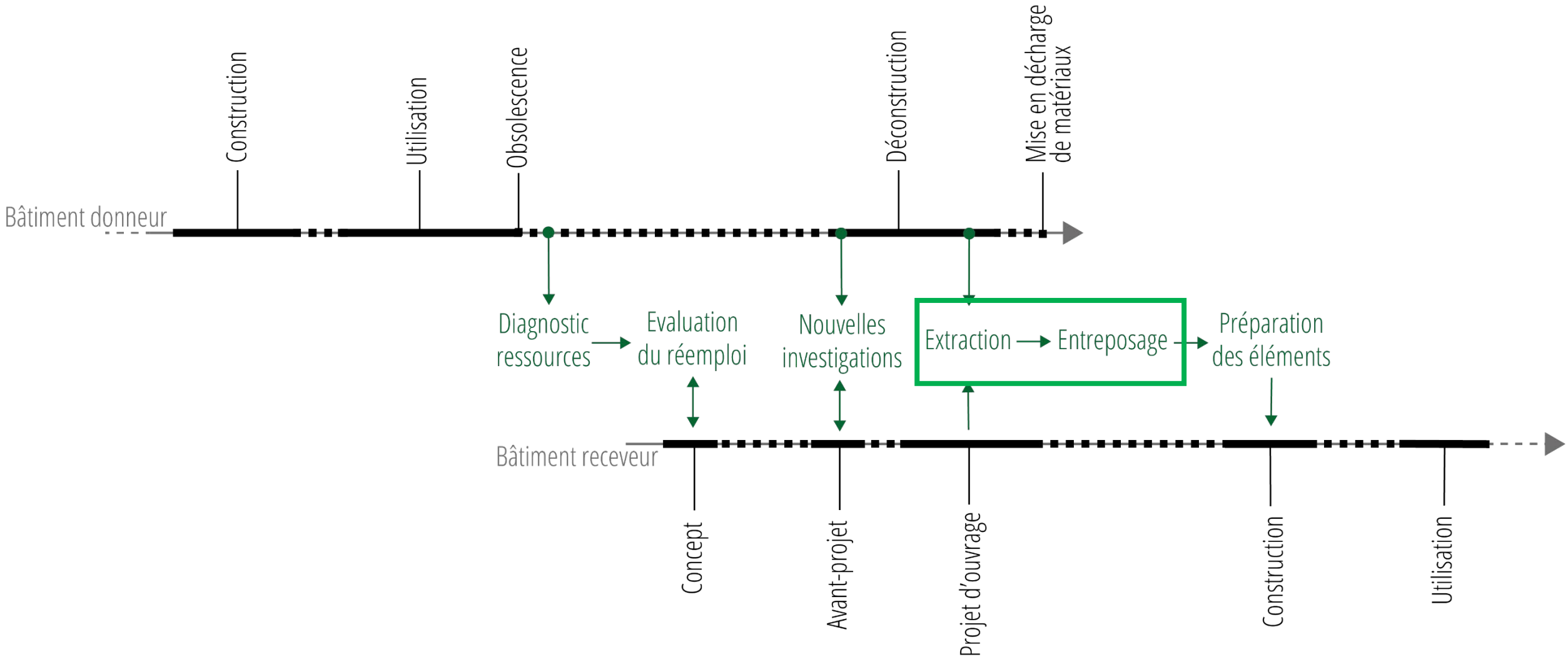
gains en CO_2-equivalent



nouvelles phases de projet



nouvelles phases de projet



déconstruction

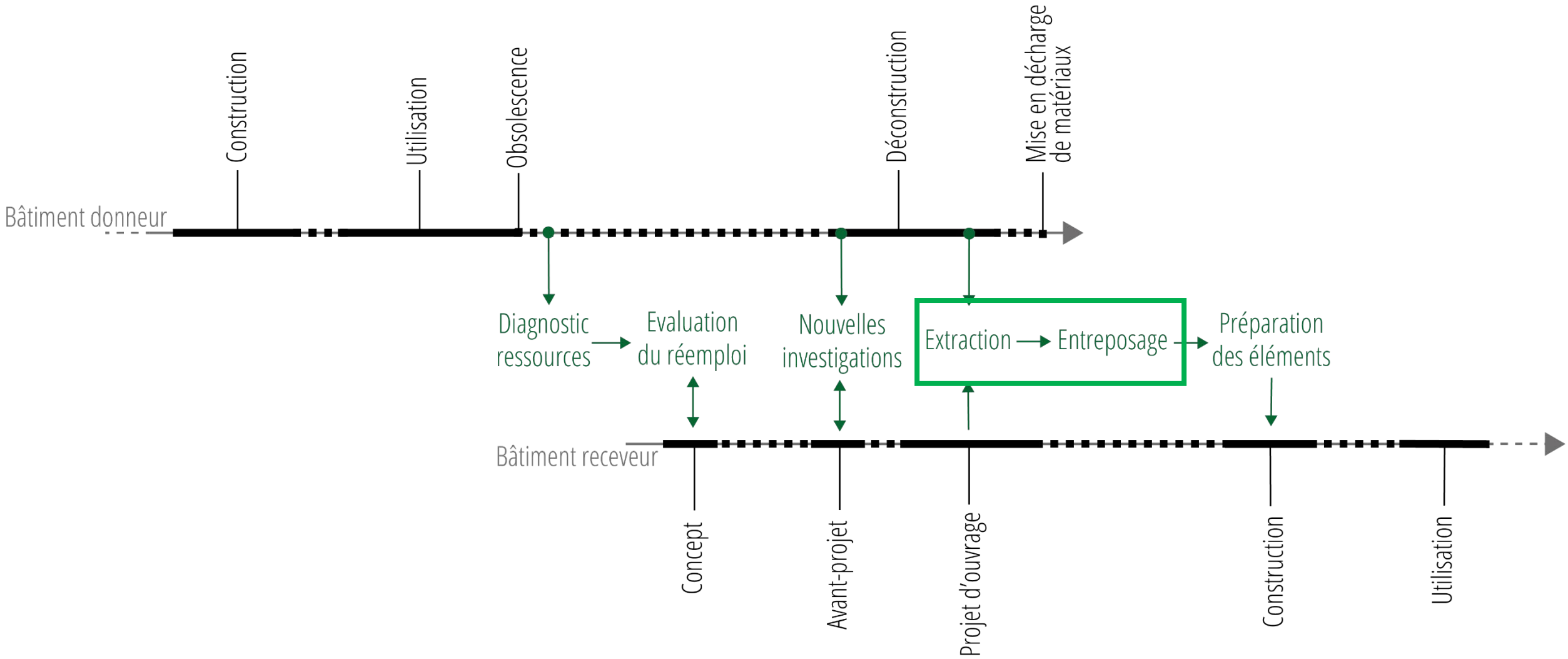




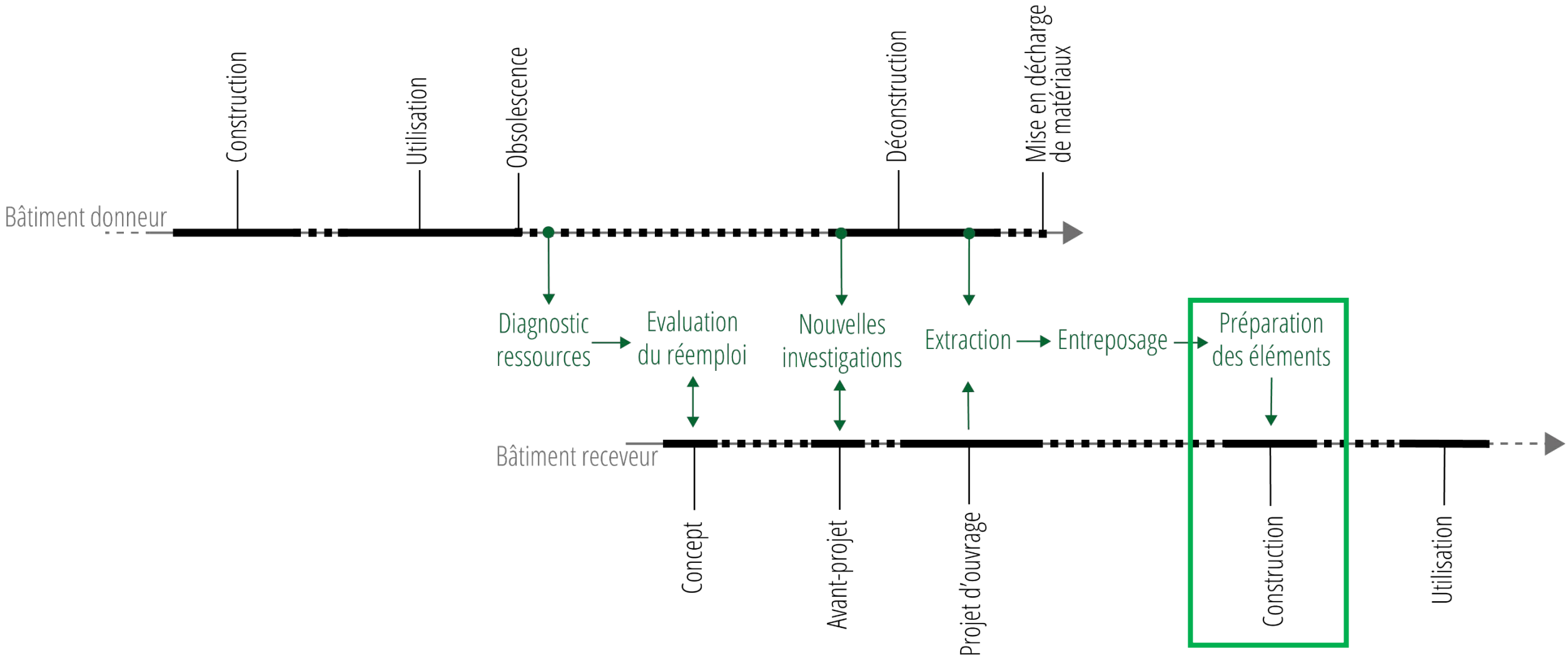




nouvelles phases de projet



nouvelles phases de projet



débris



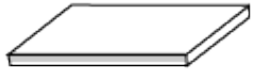


blocs



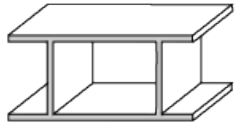


dalles



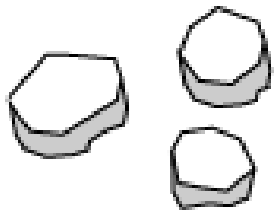


assemblages





débris

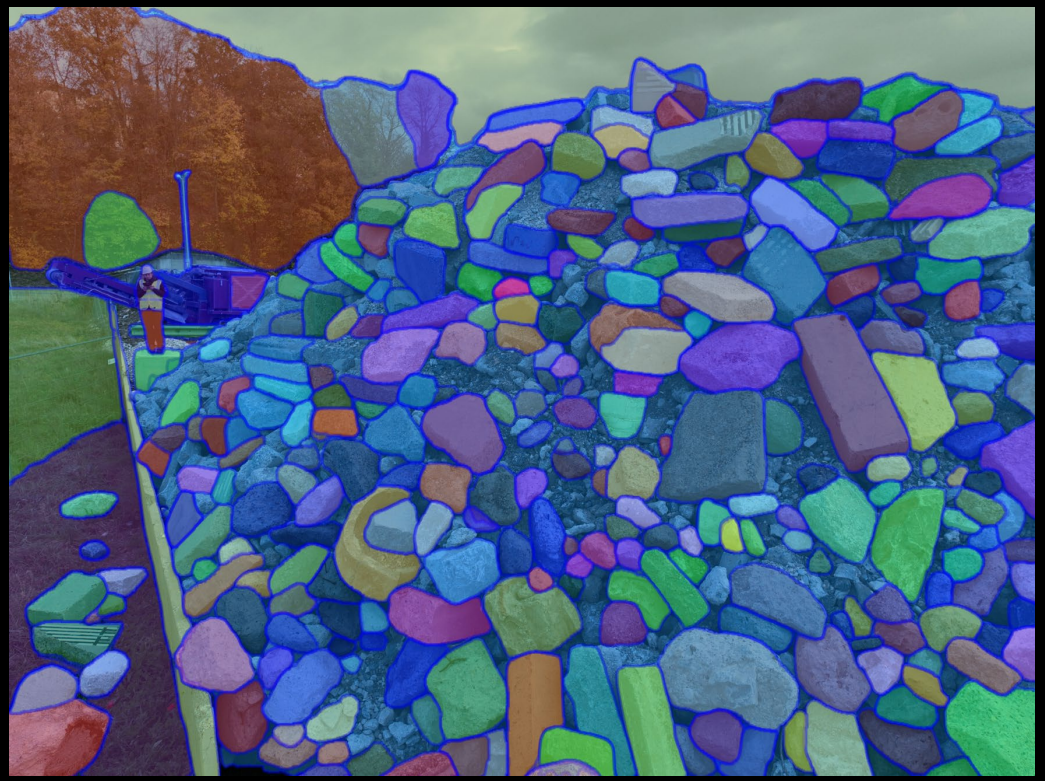






reconnaissance d’image





© Grangeot, EPFL, 2024

2D packing algorithm



© Grangeot, EPFL, 2023

prototype de mur



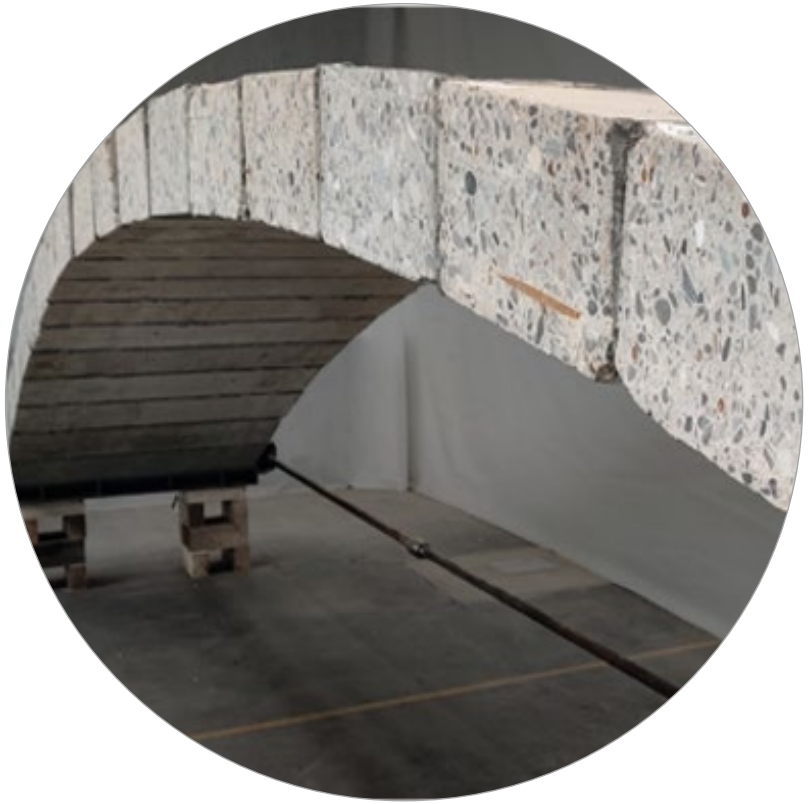


© Grangeot, EPFL, 2023

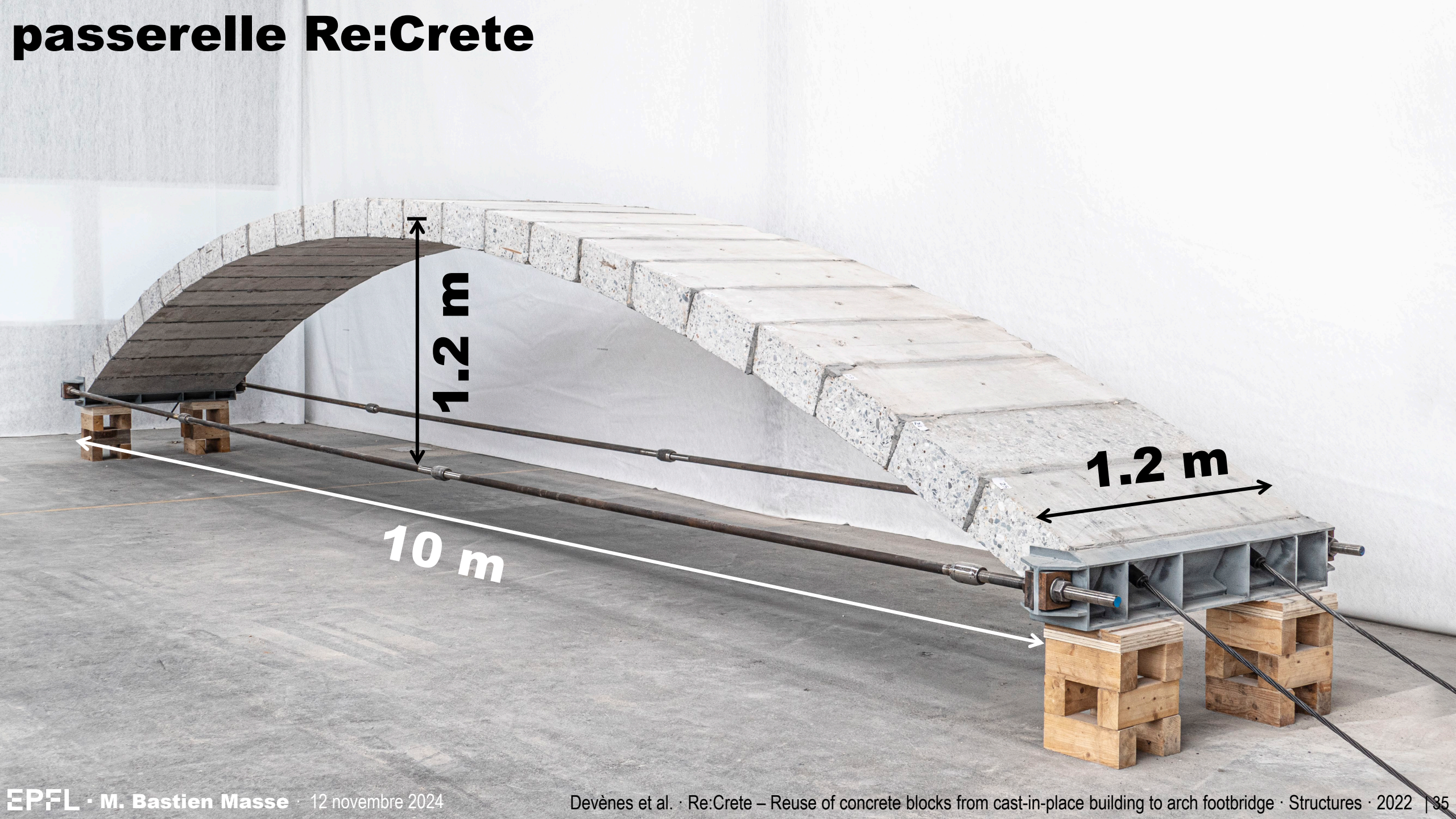
blocs





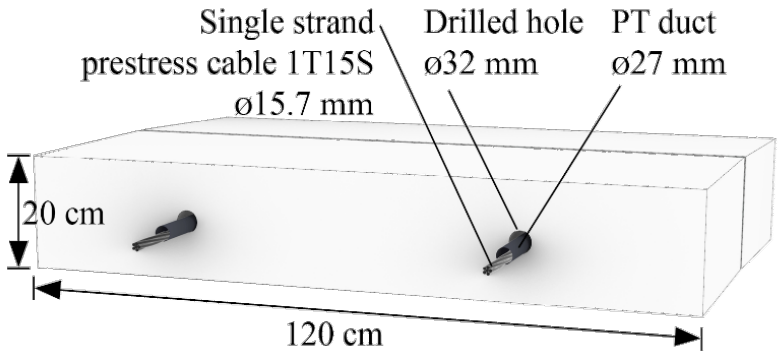


passerelle Re:Crete



Devènes et al. · Re:Crete – Reuse of concrete blocks from cast-in-place building to arch footbridge · Structures · 2022 | 35

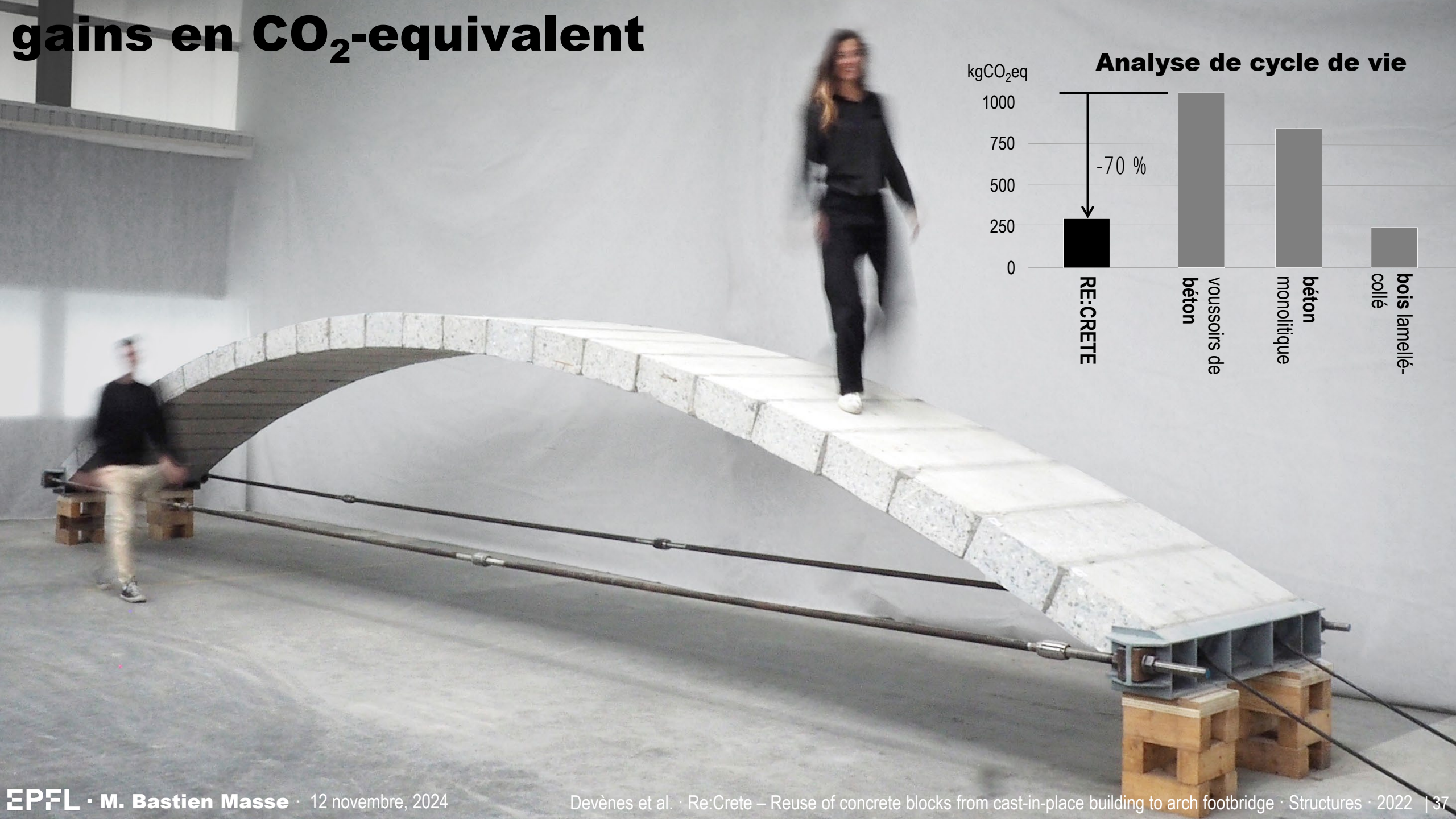
assemblage


Single strand
prestress cable 1T15S
ø15.7 mm
Drilled hole
ø32 mm
PT duct
ø27 mm
20 cm
120 cm



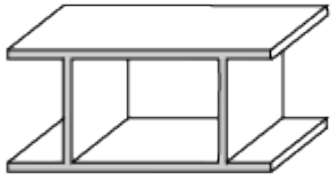


gains en CO_2-equivalent





assemblages







rebuiLT, pavillion communautaire





© Küpfer, EPFL, 2023

rebuiLT, pavillion communautaire



© PJRenaud – rebuiLT, 2023

dalles



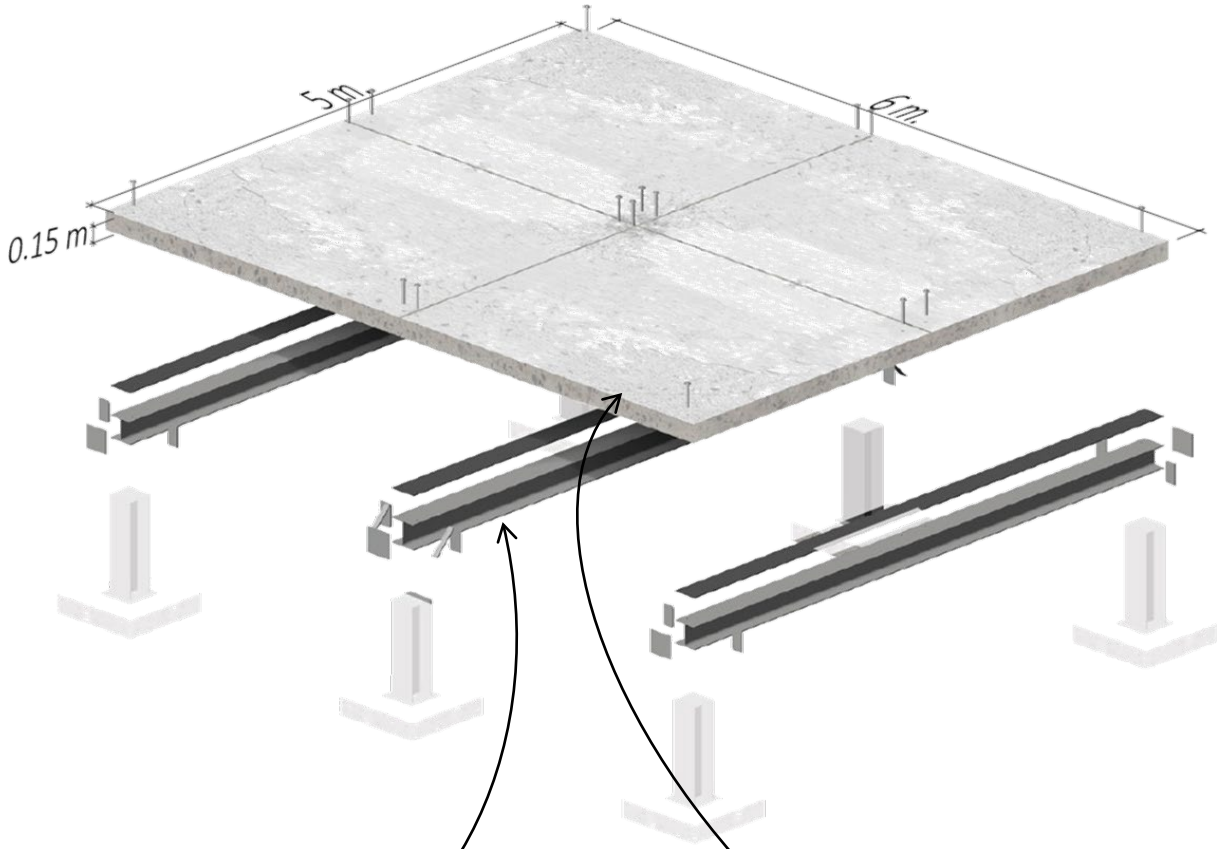




dalle FLO:RE







profilés d'acier réemployés

dalles de béton armé sciées

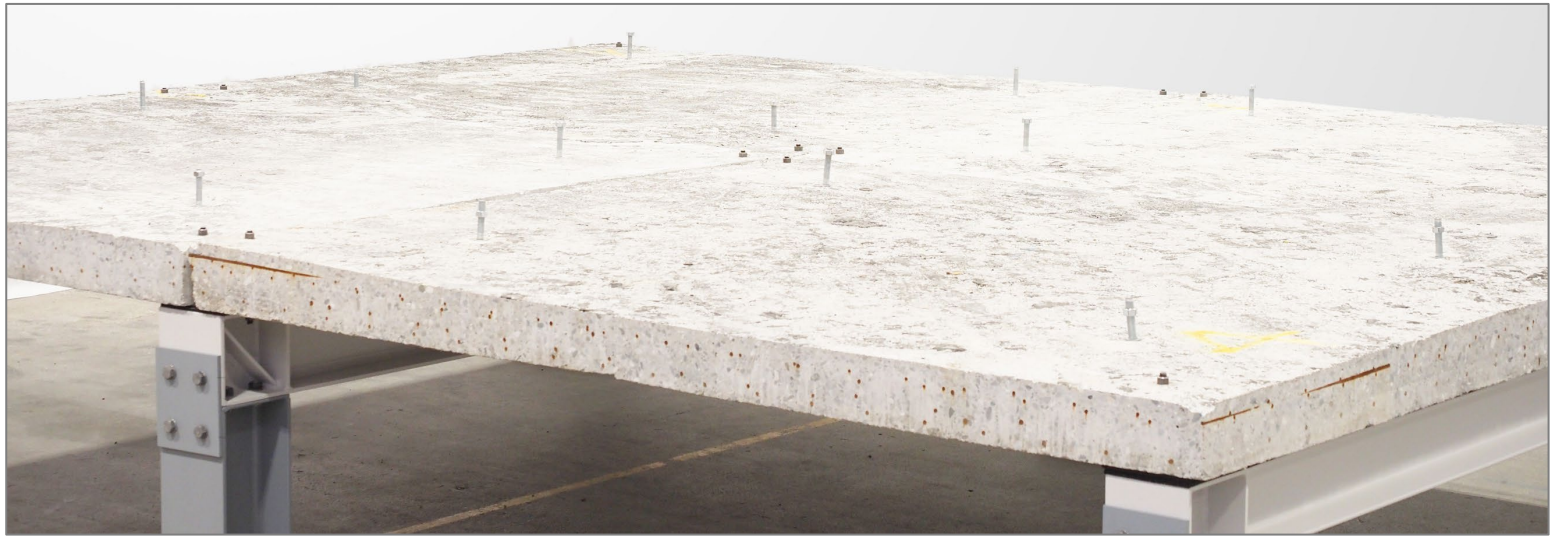




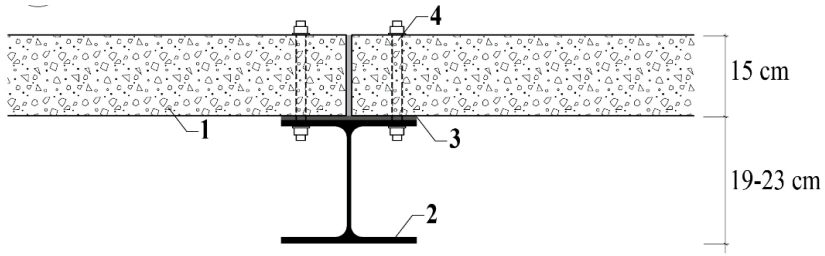
assemblage





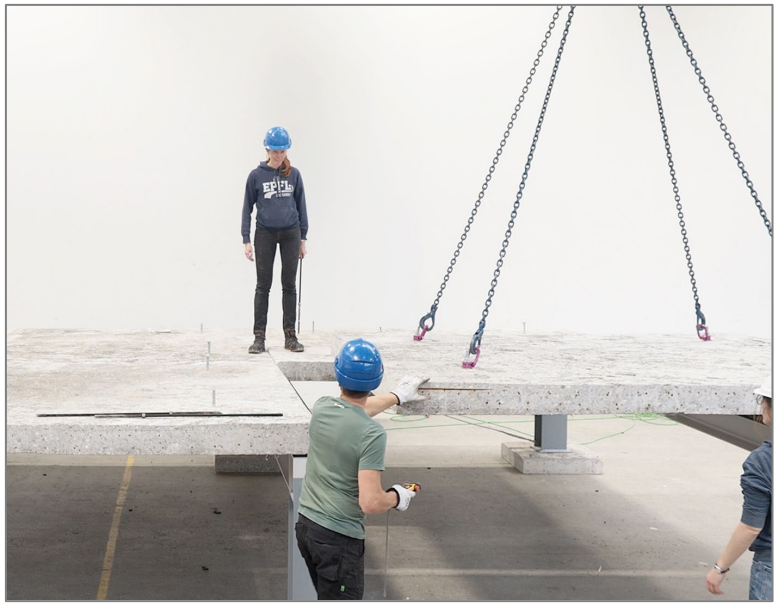


connections sèches

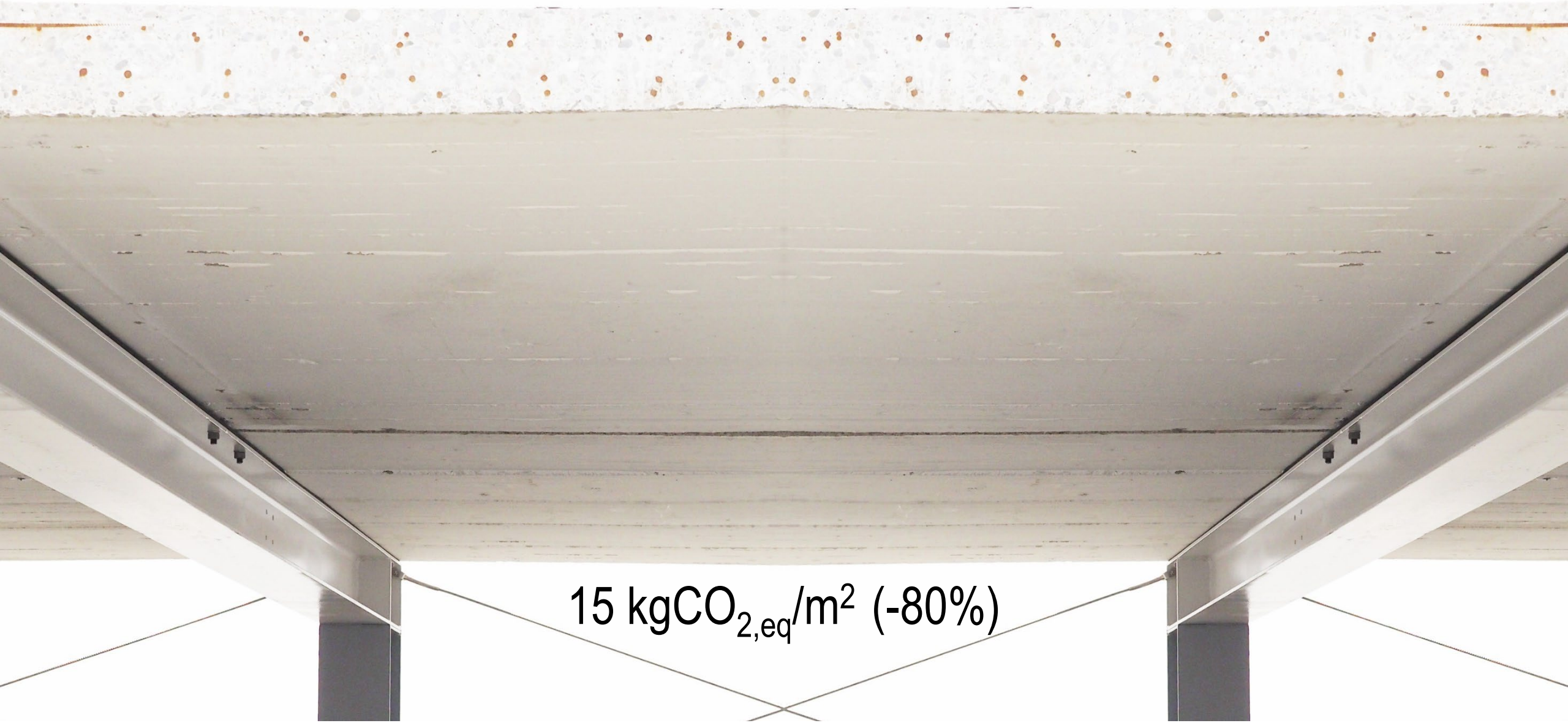


1 Reused 15-cm saw-cut reinforced-concrete slab (3 m x 2.5m)
2 Reused steel profile (HEA 200 and HEA 240) (5 m)
3 8-mm recycled rubber
4 ø16-mm prestressed threaded rod



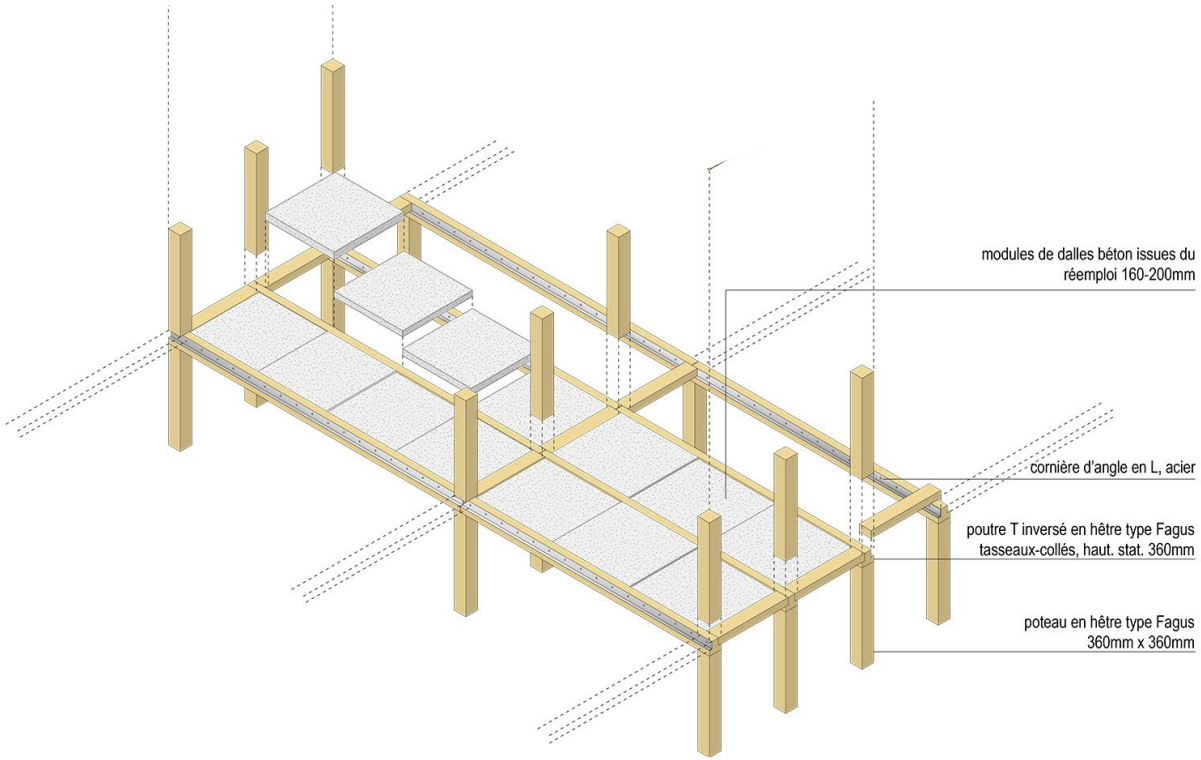


gains en CO_2-equivalent



© Küpfer, EPFL, 2023

projet en cours





© Kunik de Morsier + Bonnard & Woffray, 2024

prochaines étapes?



- 1/7 des nouvelles dalles pourraient être construites du réemploi
- partage de connaissances et d'expériences
- nouveaux processus : de la déconstruction à la reconstruction, comment certifier les éléments récupérés
- nouvelles règles de conception : de l'évaluation à la reconnexion