02 MATERIAL CATALOGUE

RISING FROM RUINS

REUSE IN UKRAINE

Content of the Folder

This second folder: 02 Material Catalogue builds directly on the theoretical and contextual foundation of Folder 01: Introduction, shifting the focus from concepts to materials. It is structured into four sections.

2.1 Overview presents an introduction to the material catalogue.

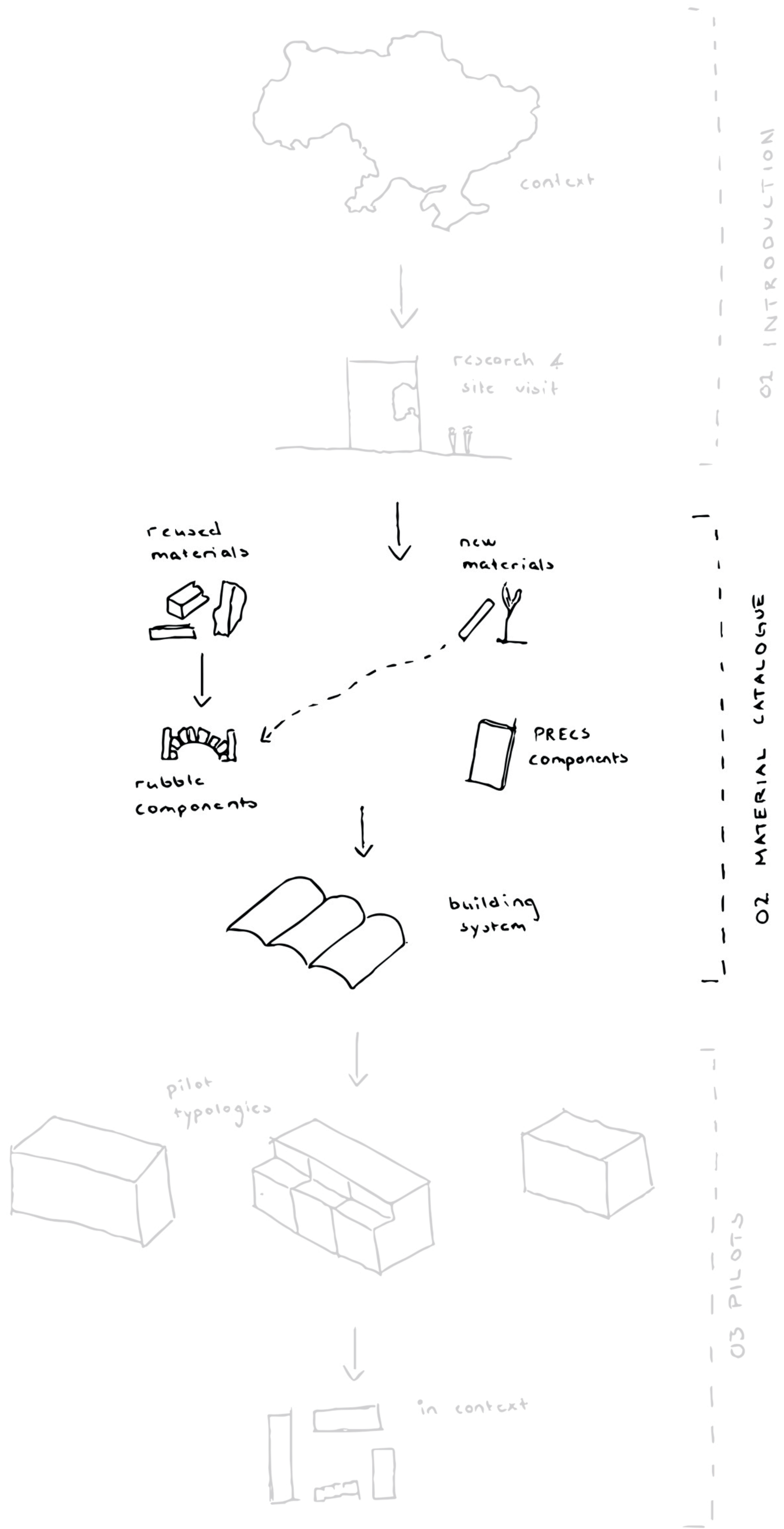
2.2 Elements documents materials, both materials reused from ruins and new materials. The section is sorted based on how the materials are sourced: through sieving, sorting or local production.

2.3 Components presents reused building components from the dismantling of the I-464 typology, and new building components made from reused elements. This section includes further testing of one of the components.

2.4 Building Systems combines the findings from the catalogue into a complete building system. It is divided into slabs, load bearing structure, partition walls, foundations, roof, cladding and insulation.

2.5 Reflections are our thoughts and learnings from working with the elements, components and the building system.

Together, these sections form a catalogue serving as the basis for the spatial and architectural proposals in the next folder 03 Pilots.



Title
Rising from Ruins: Reuse in Ukraine

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All illustrations are by us unless otherwise is stated.
Photo front page: Ruins of Irpin, Ukraine.

2.1 OVERVIEW

Introduction to the material catalogue.

Why a Material Catalogue

The material catalogue serves as a tool for mapping materials mined from ruins and their potential for reuse. By identifying and categorizing these resources and techniques for extraction, the catalogue can function as a guide for rebuilding efforts. Historically, post-war reconstruction tends to prioritize speed and industrial-scale resource use. In this catalogue, we explore how existing materials can be redirected, revalued, and reused in the rebuilding of Ukraine.

The information regarding materials is based on our findings from the landfill and damaged structures in Irpin, as well as knowledge from stakeholders and other listed sources.

Render. Balancing new and old.

2.2 ELEMENTS

This chapter introduces methods for urban mining, and a categorization of reusable materials found in ruins from our field trip to Irpin, Ukraine.

Readers Guide

Elements are here defined as parts of building components, such as brick, stones, rubble, mortar or tiles. In this section, these elements are sorted based on how they are mined:

2.2.1 Sieving: Elements extracted from ruins through mechanical sieving (1-3).
2.2.2 Sorting: Elements extracted from ruins through manual sorting. (4-16).
2.2.3 Local Production: Elements sourced locally. Ment to supplement reused materials. (17-30).

The elements listed have been given a set of properties. These are set to provide quick insight into the elements potential for reuse. The information is based on our field trip to Irpin as well as research from stakeholders and other listed sources. All entries written in *italic* indicate assumptions based on observation and general knowledge, where exact information was not found.

Criteria

Occurrence: How commonly the element was found in Irpin.

High: Frequently found in across multiple sites.
Medium: Found in several locations, but not in high quantities.
Low: Rarely found but may still be relevant if easily sourced.

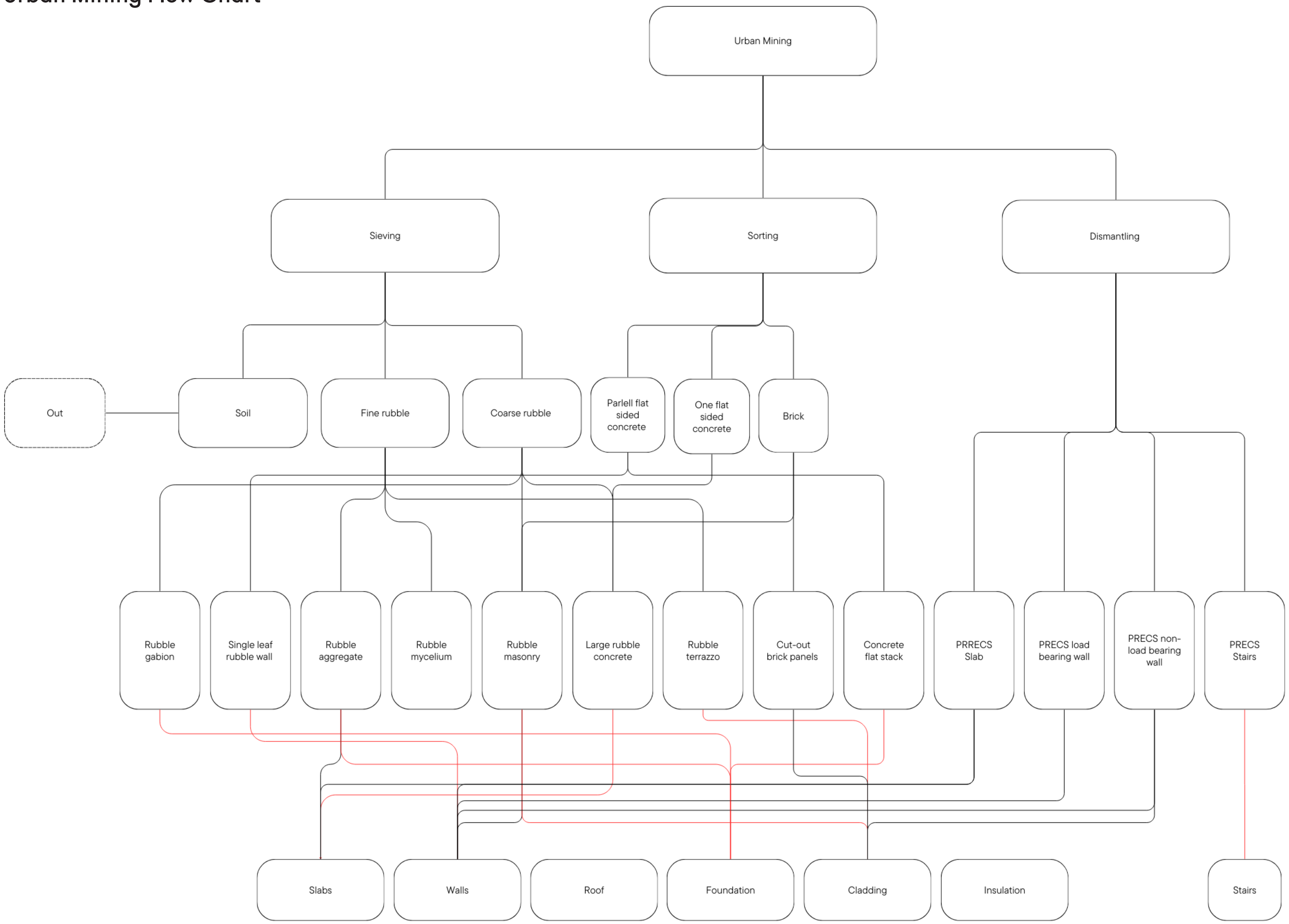
Size: Indicates the approximate size of each element.

Description: A brief qualitative text of the element. It includes original application and typical damage patterns when information is available.

Possible Toxins: Potential toxins related to each element. War related toxins are excluded, since this is dependent on each unique context and not the element itself. See appendix for more information on toxins.

Demolition of Palais Granvelle. 1931 © KIK-IRPA

Urban Mining Flow Chart



2.2.1 Sieving

Sieving is a mechanical extraction technique that sorts rubble based on size, rather than material type. It is typically done using vibrating screens or mobile sieving machines on site, as seen in the process of extracting rubble for the Warsaw Uprising mound park.[1] Sieving efficiently processes large volumes of mixed rubble, creating various material fractions. These fractions can easily be adapted to specific needs.

Pros

- High output and low labor intensity.
- Enables reuse of mass material streams with minimal processing.
- Can handle large amounts of rubble from war-damaged areas.

Cons

- Does not separate based on material composition.
- Risk of contaminating reusable fractions with hazardous residues.

Warsaw Uprising Mound Park © Toposcape

[1]Toposcape, The Warsaw Uprising Mound Park

	1. Soil	2. Fine Rubble	3. Coarse rubble
			
Description	Complex and mostly unknown composition of materials.	Fine rubble with varying material composition (mostly brick and concrete).	Larger fragments of broken concrete, masonry and other construction materials.
Size	< 10 mm	10 mm - 21mm	21mm - 100mm
Occurence	*High*	*High*	*High*
Notes	Based on the complex and mostly unknown composition of materials as well as a high risk of possible toxins, the usage is limited. Can be used for roadwork and landfill.	This fraction is suitable for use as recycled concrete aggregate (RCA) in new concrete mixes[2], non-structural screeds, road base layers, or rubble terrazzo panels.	Suitable for gabion filling, sub-base layers, coarse fill for drainage, or formwork mass. For structural mass use, visual sorting and basic crushing may be applied.
Possible toxins	Due to complex composition any toxins may be present.	Due to complex composition any toxins may be present.	Due to complex composition any toxins may be present.

Sieving rubble for the Warsaw Uprising Mound Park © Maciej Kaufman

[2]Yildizel, Recycling and Reuse of Construction and Demolition Waste.

2.2.2 Sorting

Sorting refers to the manual urban mining of reusable materials. Unlike sieving, which separates material by size, sorting can recover identifiable components such as bricks, concrete blocks or metal sheets that retain structural or aesthetic value. This process is carried out on-site, reducing transportation. In contexts like Ukraine, where labor costs remain low, on-site manual sorting is a feasible and scalable strategy[3].

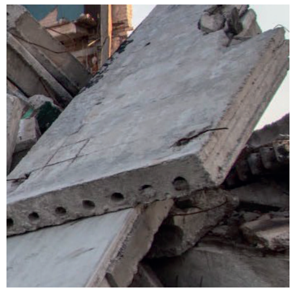
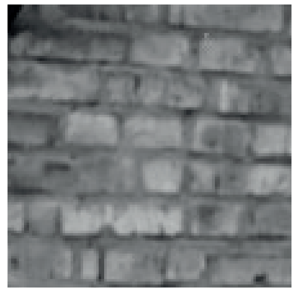
Historically, the act of sorting through ruins has been both practical and symbolic. In post-WWII Germany, groups of women known as the Trümmerfrauen (rubble women) manually cleared cities of debris and salvaging bricks by hand.[4] Their work not only enabled physical reconstruction but also marked a grassroots effort toward national recovery.[5]

Sorting is highly dependent on the composition and quality of materials at each site. In our case, the materials documented were identified during fieldwork in Irpin. The origin, condition, and prior use of the materials is therefore limited. Any reuse strategy must be informed by on-site evaluation and caution.

To ensure safe reuse, sorting must be accompanied by protective measures, basic training, and selective exclusion of contaminated or unsafe materials. See legal framework in 01. Introduction for more info.

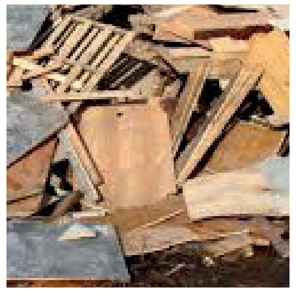
Trümmerfrauen © dpa picture alliance

[3] Sulzer, Deep-Dive into Circular Construction. [4] Kryzhanovsky, Architecture After War. [5] Amusing Planet, Trümmerfrauen.

	4. Large concrete blocks	5. Medium concrete blocks	6. Parallel flat sided concrete	7. One flat sided concrete	8. Concrete hollow slabs	9. Brick (pre 1960s)	10. Brick (post 1960s)
							
Description	Large reinforced blocks of concrete. Often solid, dense, and slightly eroded. Unknown origin.	Medium sized concrete blocks of unkown origin. Mostly intact. Not reinforced.	Concrete rubble with (at least) two parallel flat faces. Sometimes reinforced.	Irregular concrete rubble with one flat side. Sometimes reinforced.	Hollow core concrete slabs, whole or partially broken. Reinforced.	Older brick, whole or partially broken.	Newer brick, whole or partially broken.
Size	~30x100x200cm	~10x20x60 cm	~20–80 cm	~20–80 cm	Varies.	25cm x 12cm x 6.5cm	25cm x 12cm x 6.5cm
Occurence	*Low*	*Medium*	High	High	Medium	High	Medium
Sourcing	Sorting	Sorting	Sorting	Sorting	Sorting or dismantling	Sorting	Sorting or dismantling
Notes	Possibly from foundations or structural cores. Heavy and difficult to transport. May require mechanical lifting.	Unreinforced blocks allow for flexible reuse. Smaller size makes handling easier.[6]	Parallel flat sides make them suitable for stacking in walls, foundations or gabions. Easily sortable by hand. Parallel flat sides allows for 2D scanning and optimization for reuse. [7]	One flat side makes the rubble suitable for placing face down in casting etc. Can be repurposed with minimal processing.	May be repurposed for flooring, vaults, or structural slabs if structurally intact. Damaged elements lose load capacity, but can be downcycled for non-load bearing purposes[8]	Bricks are often whole or easy to dismantle from buildings pre-late 1960s because of lime mortar. Often fewer perforations, which makes cleaning easier.[9]	Portland cement mortar makes dismantling more difficult. Often chipped during recovery and perforated, making cleaning difficult. [10] Can be saw cut for panelized reuse.[11]
Possible toxins	Possible lead coatings, embedded rebars may be corroded; minimal risk if untreated.	Minimal, though mortar may contain Portland cement and older surface coatings.	Risk of asbestos or lead from surface layers if originally facade components.	Risk of asbestos or lead from surface layers if originally facade components.	Joint filler or sealants may contain asbestos	Potential traces of lead-based paint on surface; otherwise low-risk.	Mortar may contain cement dust; surface finishes may contain lead or VOCs.

[6–7] Grangeot, Upcycling concrete rubble.

[8] Küpfer, reuse of cut concrete slabs. [9–10] Skat, Perspectives of Urban Mining. [11] Lendanger, Resource Rows.

	11. Metal beams	12. Metal sheets	13. Wood Beams	14. Wood plates	15. Rebars	16. Slate
						
Description	Load-bearing metal beams, often rusted but may structurally intact if not exposed to extreme heat or impact.	Corrugated or flat metal sheets.	Timber structural beams.	Wooden panels, unkown origin.	Rusted but recoverable rebar from demolished concrete elements.	Medium sized irregular pieces, possibly from cladding or roofing.
Size	~3–6 m lengths. Various profiles.	~1–3 m length. ~0.5–1 m width	~1–3 m length. ~10–30 mm thickness	Varying size. ~2cm thick	6–14 mm diameter; ~1–3 m length	~30–60 cm plates, ~5 cm thickness
Occurence	*Medium*	*Medium*	Low	*Low*	High	High
Notes	Can be reused for structural applications if no signs of heat deformation (steel loses strength above 500°C), typically from close explotions. Otherwise, recycling is recommended.[12]	Reusable if not heavily damaged. Typically used for roofing, cladding, or facades.[13] Succsessfully reused as cladding in Building K118 Winterthuhr, Switzerland.[14]	Untreated wood beams are can be reudes after visual inspection. Minor damages may still allow use in non-load-bearing applications.[15]	Wood plates can be reused after visual inspection. Intact panels or panels with minor defects may be cut, repaired, or bonded into new boards suitable for cladding, internal walls, and non-load-bearing partitions.[16] Can also be used as formwork.	Can be reused for structural and non-structural applications. If properly cleaned and straightened reused rebars maintain comparable mechanical properties and bond strength to new rebars. Visual inspection, tensile tests, and straightening are recommended.[17]	Commonly used in soviet era housing, asbestos is almost always present.[18] Reuse is not advised, unless properly tested.
Possible toxins	Lead-based protective paint, heavy metal coatings (chromates).	Lead, PAHs.	Creosote, arsenic, or copper-based wood preservatives (if treated).	Creosote, arsenic, or copper-based wood preservatives (if treated).	Minimal (surface rust).	Asbestos.

[12]Meuser, Rebuilding Ukraine. [13–14]Skat, perspectives of Urban Mining. [15]Eversmann, Scalable Disruptors

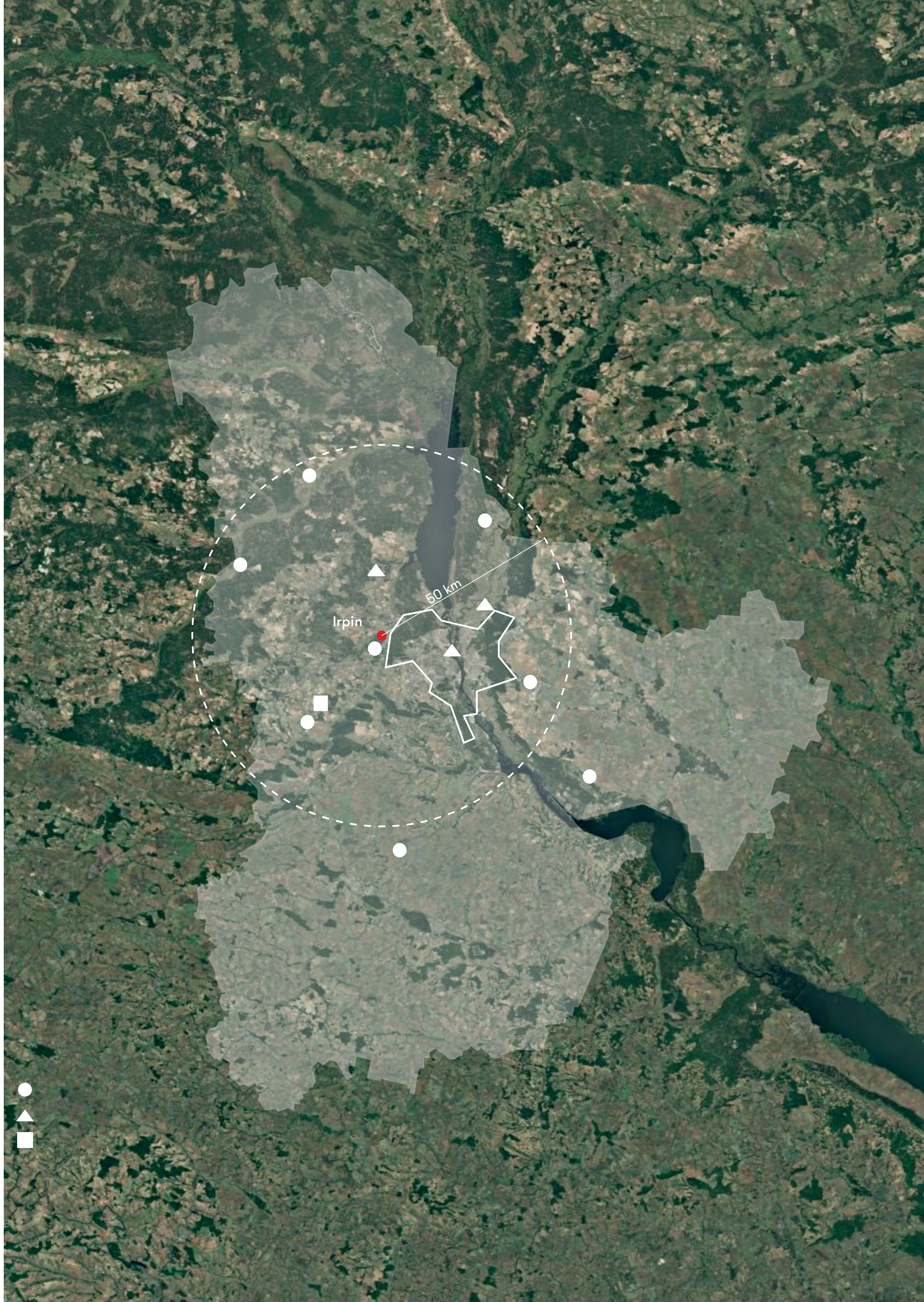
[16]Eversmann, Scalable Disruptors [17]Bsisu, Steel Bars from Demolished Structures. [18]Skat, perspectives of Urban Mining

2.2.3 Local Production

In order to reuse elements from ruins, some supplementing materials are needed. Sourcing and producing these materials locally are both a logistical and strategic consideration.

Minimizing transport distances significantly lowers emissions associated with material production and delivery. However, the term “local” is highly dependent on the context. It can refer to a neighborhood, a municipality or a region. ReThink estimates that for heavy or bulky building material, reuse is only economically and environmentally viable within a limited radius from the source location (nominally 50km).[19] For this thesis we define the term local as +/- 50km to Irpin.

Sourcing and producing materials locally can contribute to shaping a more resilient rebuilding process, while lowering the climate impact. Local production reduces dependency on imports, strengthens the regional economy, and creates job opportunities within the communities undergoing reconstruction.[20] The accompanying map highlights key locations where some supplementing materials can be sourced and processed.[21]



[19_20] Sulzer, Deep-Dive into Circular Construction [21] Rebuild Ukraine, Map of Natural Resources.

Bio-based Materials

Bio-based materials can be used either as supplements to rubble, or where reused elements are insufficient (e.g. for insulation). Local, renewable materials such as wood, straw, hemp, and clay are increasingly considered in Ukraine for their low embodied carbon and good thermal properties. These materials offer a sustainable alternative to conventional construction products and contribute to reducing emissions.[22] While the main focus of this thesis is on reuse and circular construction, bio-based materials are included here as they represent a complementary strategy with strong potential for local production, carbon reduction, and as a supplement to reuse.

17. Mycelium

Grown from fungal root systems. Lightweight, compostable, and moldable.[23]

18. Cork

Lightweight and moisture-resistant. Renewable and highly insulative.[24]

19. Hemp

Agricultural byproduct with high insulation capacity. Typically combined into hempcrete or hempwool. Long history of use in walls and roofing.[25]

20. Reeds

Locally abundant plant used historically in thatching.[26]

21. Straw

Agricultural byproduct with strong insulation capacity. Long history in walls and roofing.[27]

22. Clay

Abundant in many regions close to Irpin. Can be used raw or stabilized. Hygroscopic and breathable.[28]

23. Wood

Local forestry can provide CLT, glulam, or reused timber. [29]

[22]Sulzer, Deep-Dive into Circular Construction

[23]Guan, Mycelium. [24] Yadav, The use of cork. [25]Hempitecture, Hempwool. [26-27] Lviv Historical Museum [28-29] Rebuild Ukraine, Map of Natural Resources.

Reuse Centrals

Several reuse initiatives are emerging in response the reconstruction needs in Ukraine. Light-weight, standardized components such as doors, windows, window frames, sinks and toilets can easily be reused.[30] These elements, often overlooked, offer substantial environmental and cost-saving benefits when recovered and repurposed.

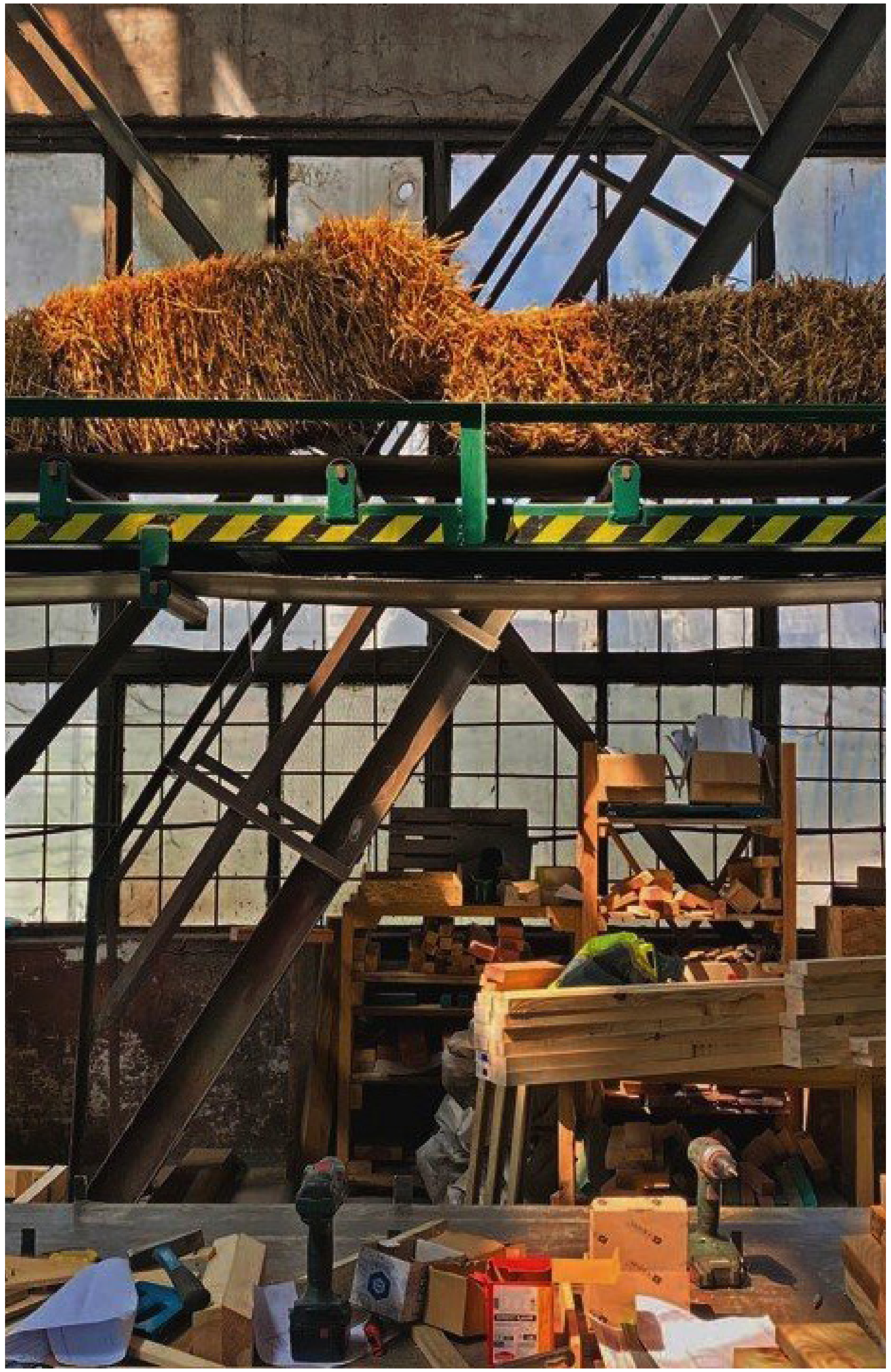


Image from a Reuse Central Rebuild Ukraine, Map of Natural Resources.

[30]Skat, Perspectives of Urban Mining

Recycled Materials

Following the hierarchy of the delft ladder, recycling (immobilization with useful new application) can be considered when reuse is not possible. This approach requires more energy, but is often less energy intensive than sourcing and producing new materials.[31]

24. Glass

Glass has a complete and repetitive cycling loop. Can be recycled into new glass products, insulation materials, used in brick making or in ceramics.[31]

25. Rebars

Rebars from reinforced concrete can be sorted out and recycled. [32]

26. Gypsum

Gypsum is commonly used as internal cladding in Ukraine and can be recycled in an infinate loop.[33]

27. EPS

Expanded polysterine panels are commonly used for insulation in soviet-era housing. Can be recycled into new insulation.[34]

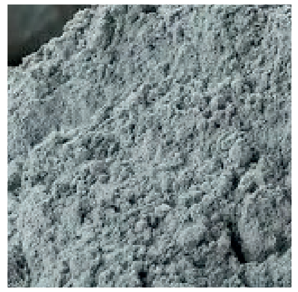
28. Metal

Metal count for up to 4% of waste in Ukraine. Metal recycling in Ukraine is widespread and economically viable.[35]

29. Wood fibre

Pieces of wood unsuitable for reuse can be processed into chipboard and fiber boards, when paint and oils are not present [36]

30. Concrete



Can be crushed into aggregate for use in new concrete or road base, reducing landfill waste and demand for virgin materials. [37]

[31] Skat, Perspectives of Urban Mining

[31_32_33_34] Skat, Perspectiveese of urban mining. [35_36] Drozdov, New Living Environement. [37] S3, Rebuilding Ukraine

2.3 COMPONENTS

This chapter introduces reused components from the I-464 typology and explores the potential of reusing rubble to make new components.

Components Readers Guide

Components are defined as a part of a building, such as columns, beams and prefabricated walls and slabs. These are divided into the following categories:

2.3.1 Dismantling: standarized building components dismantled from the I-464 typology (number 1-4).
2.3.2 New components: Components combined from elements in part 2.2 elements (number 5-15). For component 15. we have tested several variations using different materials, shown in variation 15.1 – 15.3.

Properties
All components have the following properties. Given values is marked in bold, whereas proposed values are marked in italic.

Reuse Element: The proposed reused element(s)

New Element: The proposed supplementing element(s)

Dimensions: Given or proposed dimensions.

Load bearing: Type of load bearing capacity. (compression based or none)

Finish: Possible finishes.

Application: Where it appears in the building system.
Feasibility: Own assessment of how likely the use of the component is, on a scale from 1-5 where 1 is least likely and 5 is most likely.

Indicates where the compoent appears in the pilot typologies in the folder 03 Pilots.

2.3.1 Dismantling

This section is based on the dismantling and reuse of components from the I-464 housing system. The components from internal zones are especially suitable for reuse, since they are protected from environmental degradation and (some) war-related damages. Due to this we have limited the selection to internal components.

Dismantling and Assessment
To dismantle the components, knowledge and assessment of the typology is required. Because of the standardization of the I-464 building system, the dismantling system developed and tested in Irpin can be applied wherever this typology is found.

Joint knowledge: Understanding how elements are connected is crucial to prevent damage during removal.[38]

Dismantling Methods: Diamond sawing, hydro-blasting and crane-assisted lifting.[39]

Assessment Tools: Rebound hammers, ground-penetrating radar help evaluate the structural quality of dismantled components with minimal damage.[40]

Handling & Storage: Elements must be transported and stored with care to retain structural integrity. Can be stored on site.[41]

[38_39_40] Küpfer, Reuse of Concrete Components. [41] Asplan Viak

Examples on precast concrete dismantling projects. See full list in Appendix.

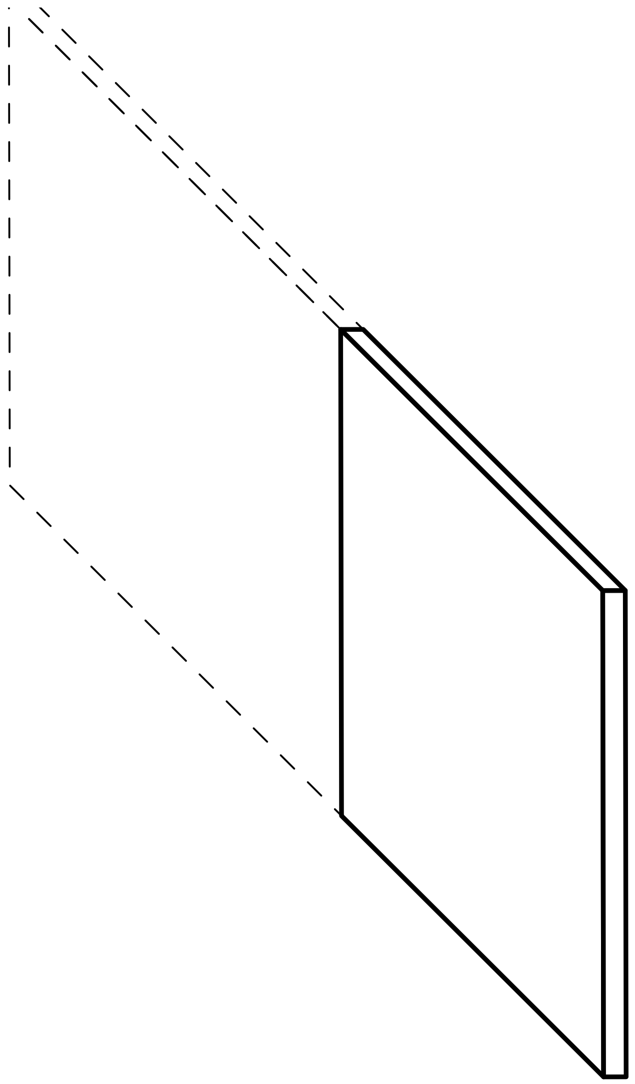
1. PRECS Slab

Reused	PRECS Slab	**Finish**	Covered or exposed
New elements	-	**Application**	Walls, slabs
Dimensions	10 x 570 x 318cm.		
Load bearing	Compression based	**Feasability**	●●●●○

Sources
Küpfer, Reuse of Concrete Components.
Asplan Viak, Mulighetsstudie: Ombruk av plasstøpt betong

Gallery House

2. PRECS Load bearing wall

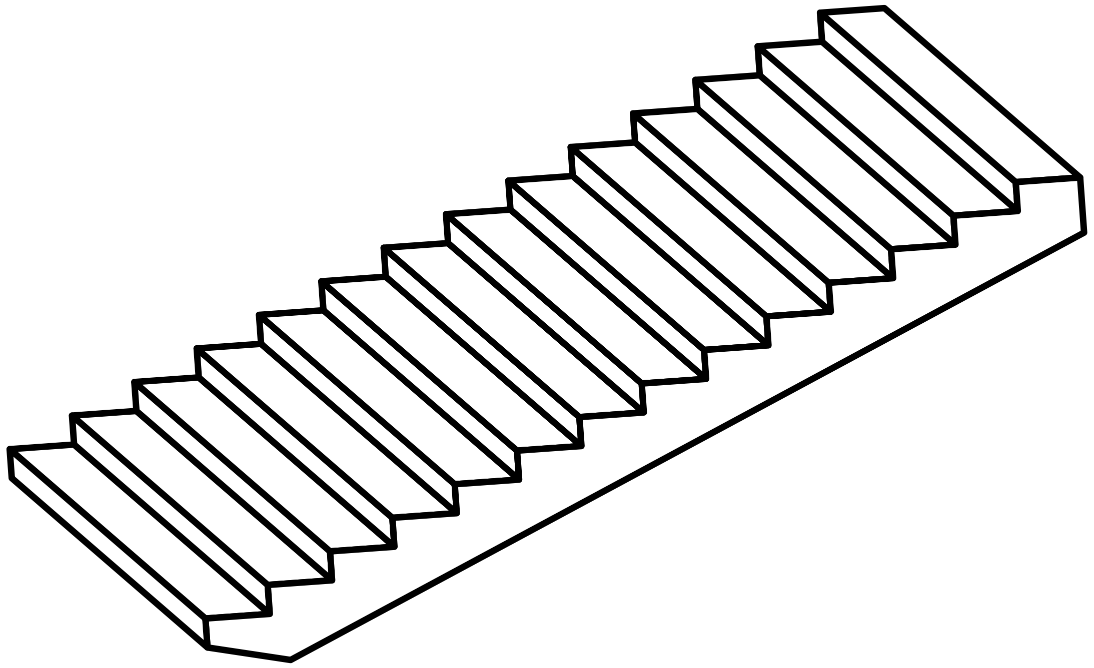


Reused	PRECS Slab	**Finish**	Covered or exposed
New elements	-	**Application**	Walls, slabs
Dimensions	12 x 258 cm. Length vary from 102 - 601 cm		
Load bearing	Compression based	**Feasability**	●●●●○

Sources
Küpfer, Reuse of Concrete Components.
Asplan Viak, Mulighetsstudie: Ombruk av plasstøpt betong

Gallery House

3. PRECS Stairs

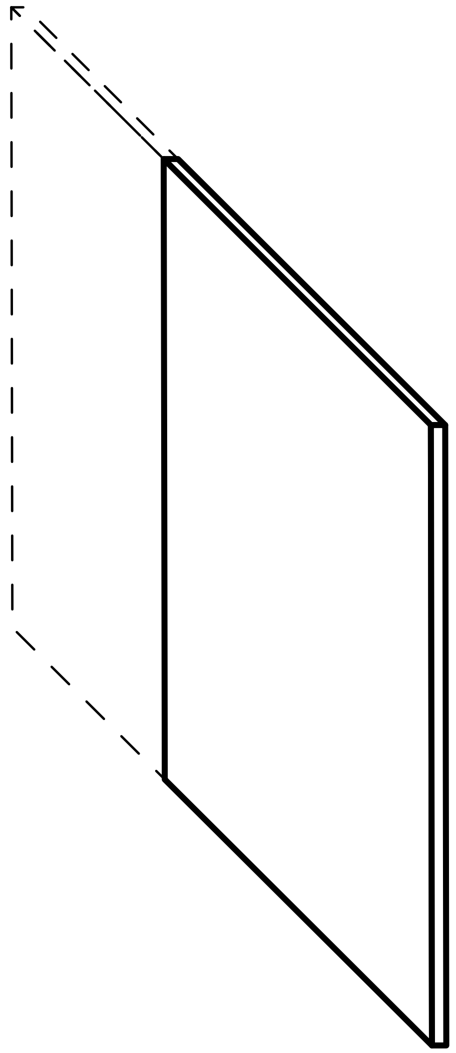


Reused	PRECS Slab	**Finish**	Covered or exposed
New elements	-	**Application**	Walls, slabs
Dimensions	10 x 570 x 318cm.		
Load bearing	Compression based	**Feasability**	●●●●○

Sources
Küpfer, Reuse of Concrete Components.
Asplan Viak, Mulighetsstudie: Ombruk av plasstøpt betong

Gallery House

4. PRECS non-load bearing wall



Reused	PRECS Slab	**Finish**	Covered or exposed
New elements	-	**Application**	Walls, slabs
Dimensions	6 x 258 cm. Length vary from 76 -157cm.		
Load bearing	Compression based	**Feasability**	●●●●○

Sources
Küpfer, Reuse of Concrete Components.
Asplan Viak, Mulighetsstudie: Ombruk av plasstøpt betong

Gallery House

2.3.2 Rubble Components

Building on the research and documentation from the element part of the catalogue, this section explores the next phase: testing and developing new building components from rubble materials. These components are developed in response to the availability and properties of materials found in ruins. The approach combines insights from historic rubble construction techniques, contemporary research, and our own experiments. By reinterpreting the material knowledge gathered earlier, we aim to push the exploration further, asking how rubble can be reused and redefined as new architectural components

While grounded in reference projects, this section deliberately focuses on testing new combinations, scales, and structural roles for rubble. It moves beyond documentation to explore experimental strategies for reuse and propose innovative applications for circular construction.

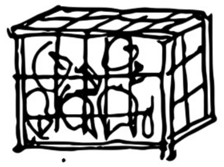
We treat rubble not as waste, but as a resource for architectural experimentation, developing prototype components that suggest new directions for material reuse in post-disaster contexts.

Louis Kahn said: “You say to a brick, ‘What do you want, brick?’ And brick says to you, ‘I like an arch.’”[42] In this part of the catalogue we say to rubble: “What do you want, rubble?”

[42]Kahn, Conversations with students.

5. Rubble Gabion

Rubble gabions use any coarse rubble in metal cages. It can be made in different variations, such as a continuous gabion pouring the rubble on site or as cages - easily transported and stacked. They offer a high-volume reuse solution with minimal craftsmanship requirements but depend on high metal use. This component offers a visible reuse of rubble in its raw state. It can be used in facades, as point foundations or for retention walls and benches.



Gabion retention wall in Kyiv, Ukraine. February 2025.

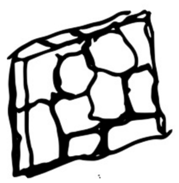
Reused elements	3. Coarse rubble	**Finish**	Raw or covered
New elements	Recycled metal cages	**Application**	Cladding, foundation
Dimensions	Variable e.g 110x120x60cm		
Load bearing	Compression based	**Feasability**	●●●○○

Sources GXN Innovation, Ressource Blokken

Point foundation in Row House

6. Single Leaf Rubble

The single leaf rubble wall is based on experimental research from École Polytechnique Fédérale de Lausanne (EPFL). It consists of vertically stacked concrete rubble with parallel flat sides, using digital tools for planning and robotic stacking. According to this research, the structure can support up to three stories as a load bearing wall. This system minimizes material processing but demands labor and computational resources. We extend this research by testing how the system can be applied as a partition and load-bearing wall for low-rise construction, focusing on minimal material processing with manual stacking and potential plaster finishes for a more refined finish.



Single leaf concrete wall prototype © Maxence Grangeot

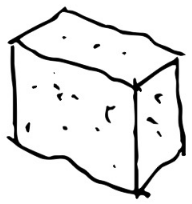
Reused elements	Parallel flat sided concrete.	**Finish**	Covered or exposed stone
New elements	Mortar, metal dowel.	**Application**	Walls
Dimensions	Variable. Load bearing wall up to three stories tall.		
Load bearing	Compression based.	**Feasability**	●●●○○

Sources Grangeot, upcycling concrete rubble

Load bearing partition wall in Row House

7. Rubble Aggregate

This strategy reuses small rubble fragments as filler in new concrete mixes. Studies from Chang'an university show that 20% substitution rates retain mechanical performance, while higher rates compromise strength. We hypothesize that this approach can reduce the carbon footprint where new concrete is needed, such as basements used for bomb shelters where structural safety certainty is the main priority for safety. This approach can also subtly show the inhherent memory of the material when exposed in concrete surfaces.



Arkwright © Square feet architecture.

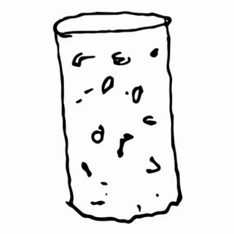
Reused elements	Fine rubble	**Finish**	Covered or exposed
New elements	Cement	**Application**	Slabs, walls, roof, foundation
Dimensions	Variable		
Load bearing	Compression based	**Feasability**	● ● ● ● ●

References Ajayebi, Optimal Replacement Ratio of RCA.
Square Feet Architects, Arkwright)

Basement in Lamella

8. Rubble Mycelium

The Mycelium rubble is an experimental component, binding brick rubble with living mycelium acting as a natural adhesive. Prepared by mixing porous rubble and inoculating with mycelium spores under controlled conditions. The brick rubble is particularly suitable, due to its pours compositing and rough surface, giving the mycelium something to grip. This component has limited structural capacity but presents a radically different approach to regenerative building.



Rubble Works mycelium column © Rublazzo

Reused elements	Fine rubble	**Finish**	Covered or exposed
New elements	Mycelium	**Application**	Walls
Dimensions	Variable		
Load bearing	Compression based	**Feasability**	●○○○○

Sources David Chipperfield Arhitects, Rubble-Works.

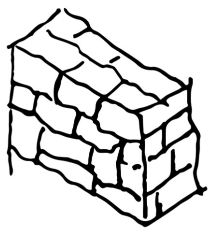
9. Rubble Masonry

As discussed in 01 Introduction: a brief history of reuse, building with irregular, reused materials have long been a standard practice. Ranging from ancient spolia to vernacular rubble masonry, there are several precedents for this. Our exploration continues this tradition, using available brick and concrete elements to test rubble's potential in post-disaster rebuilding.

Due to its irregularity, rubble is generally unsuitable for modern load-bearing walls. However, it can be used as facade cladding or non-structural walls. Inspired by Wang Shu's Ningbo Historic Museum, where salvaged materials were reinterpreted using the Wa Pan technique , we propose similar applications to embed memory and texture into new structures.

When using salvaged bricks, specific bonds such as English bond and rowlock bond allows for reuse of both whole and damaged bricks.

This requires skilled masonry, but can provide an expressive facade carrying several layers of memory.



Rubble Works masonry wall © Rublazzo

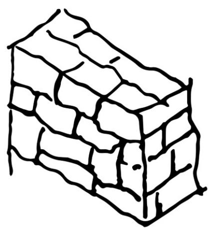
Reused elements	Rubble	Finish	Covered or exposed
New elements	Mortar	Application	Walls, cladding
Dimensions	Variable		
Load bearing	Compression based	Feasability	●●●●○

Sources David Chipperfield Arhitects, Rubble-Works.
Wang Shu, Ningbo Historic Museum.

Cladding in Lamella — Cladding in Row Houses

10. Large Rubble Concrete

This component is inspired by Erling Viksjø's "naturbetong", a technique where he used large stones embedded in prefabricated concrete blocks. We propose using large rubble as outer mass to reduce cement and expose the rubble in a controlled way. These components can both be used as load-bearing walls and slabs. Due to the distribution of forces in the slabs, the top part would utilize the compressive strength of the rubble, while the bottom would hold tension through a binding layer of reinforced concrete.



Viksø nature concrete wall

Reused elements	Coarse rubble	Finish	Covered or exposed
New elements	Cement	Application	Walls, slab, roof
Dimensions	-		
Load bearing	compression based	Feasability	●●●●○

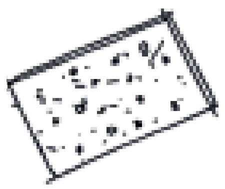
Sources

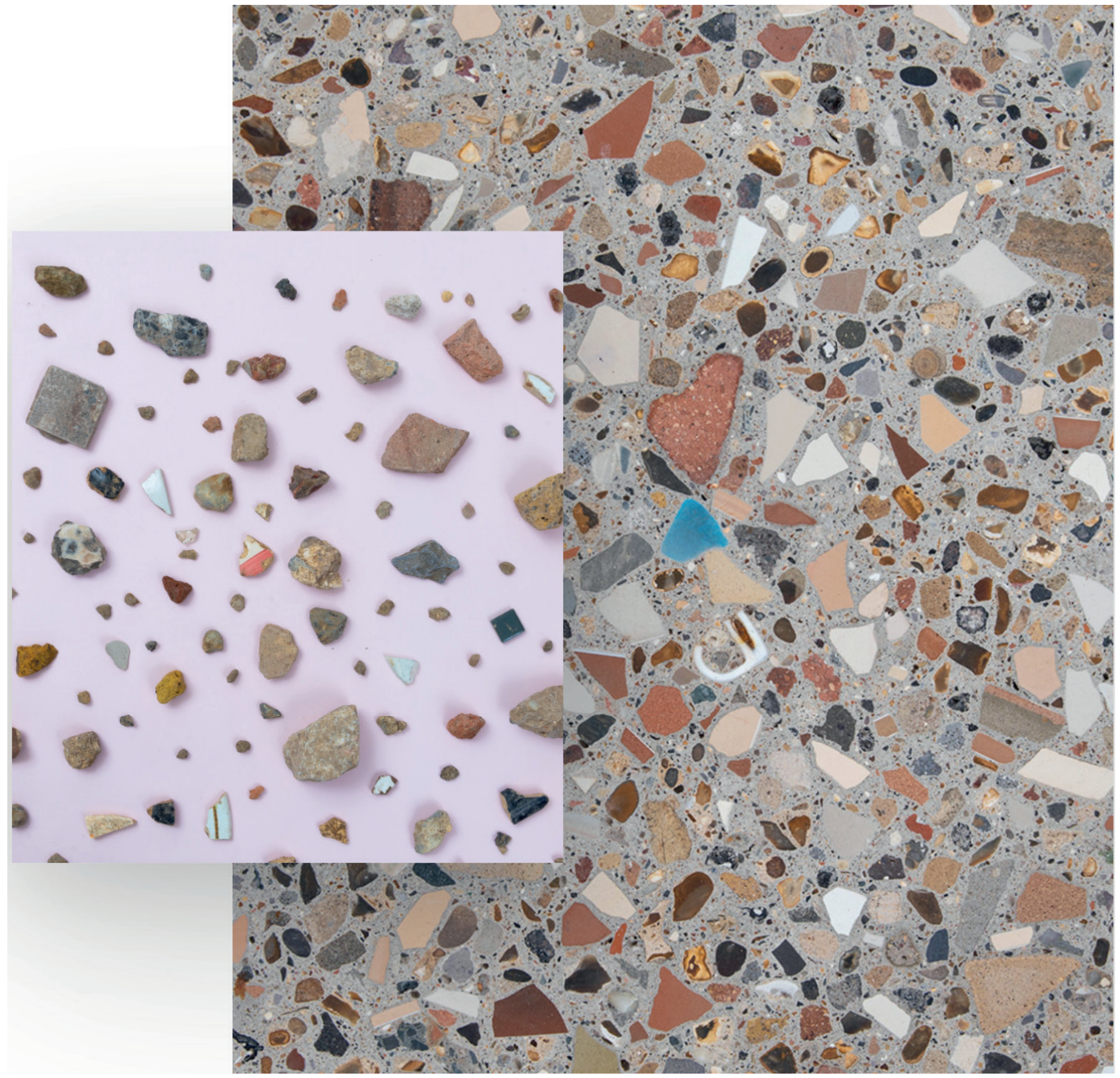
Viksjø, Naturbetong
Fabel Arkitekter, Ensjø concrete.

Load bearing wall and flooring in Lamella

11. Rubble Terrazzo

This component uses a traditional terrazzo technique with fine rubble as addition. The rubble is added to cement or resin binders and poured into molds, before it is cut to size. Alternatively, it can be casts in-situ and sanded down. While this technique is energy-intensive and aesthetic rather than structural, the rubble terrazzo allows for a unique combination of color and textures, and can be a subtle way of embedding memory into new structures.





Rubble Terrazzo © Rublazzo

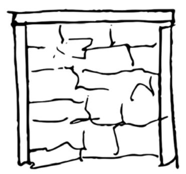
Reused elements	Fine rubble	Finish	Variable.
New elements	Cement (binder)	Application	Cladding, flooring
Dimensions	Variable e.g 60 x 30 x 5 cm		
Load bearing	No	Feasability	●●●●○

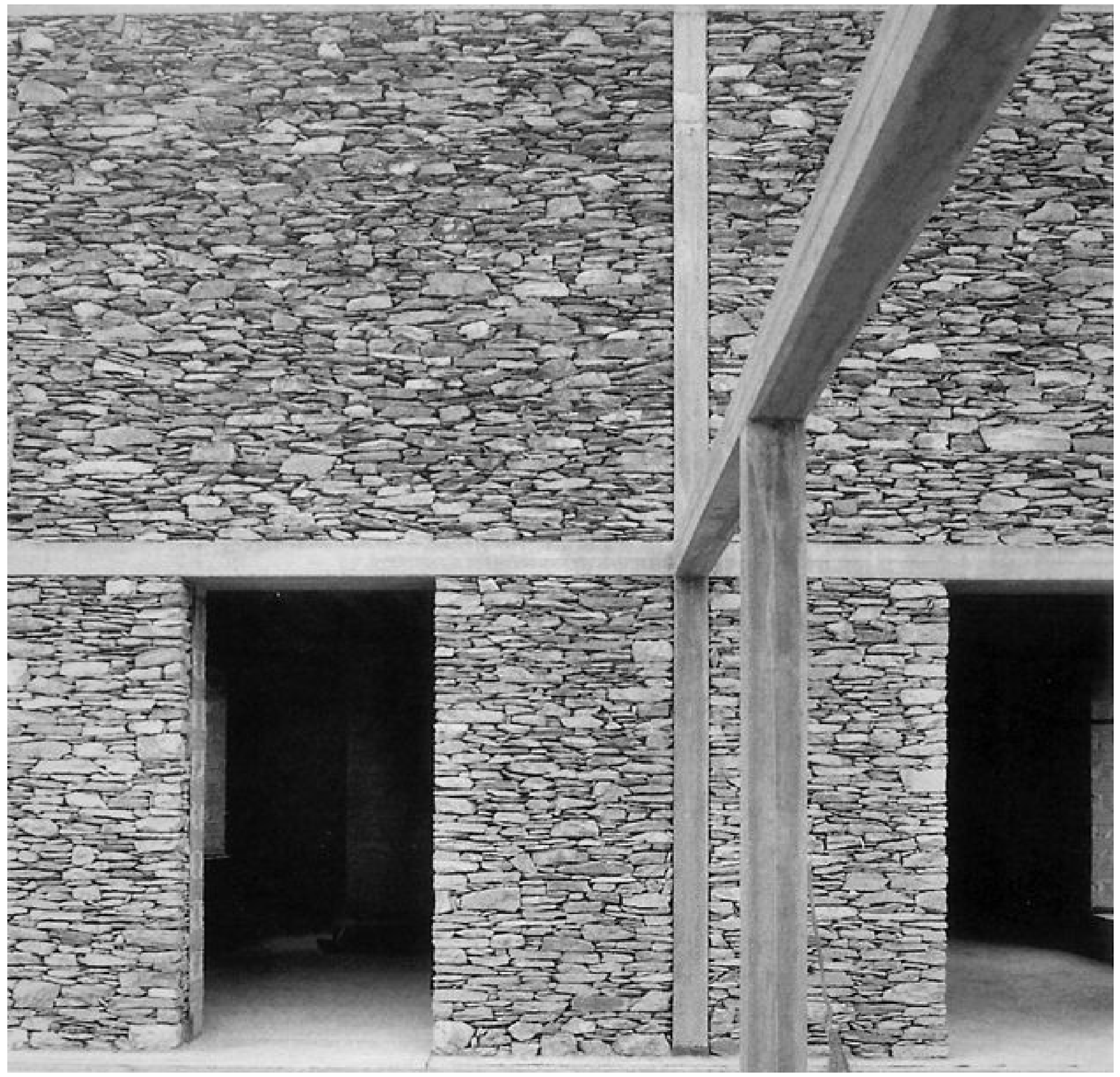
Reference Rubblazzo, Rubble terrazzo.

Cladding in Row Houses

12. Rubble Stud Framing

Rubble infill within wood or metal stud frames was inspired by the Fur Stone project. This project uses stone as infill, but we hypothesize that rubble can be equally efficient. These structures can be designed for disassembly, maximizing low-skill assembly potential while utilizing large volumes of low-grade rubble.





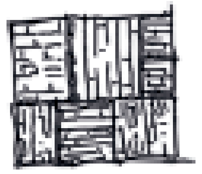
Fur Stone © Herzog & de Meuron

Reused elements	Rubble (any)	Finish	Exposed or covered
New elements	Framing (timber, metal)	Application	Walls
Dimensions	Variable		
Load bearing	Compression based framing	Feasability	●●●●○

Sources Herzog & de Meuron, Fur Stone.

13. Cut-out Brick Panels

Lendager Architects' project in Copenhagen inspired our exploration of how brick walls with Portland mortar can be cut into modular panels for facade reuse. We propose adapting this technique for Ukrainian post-1960s buildings. These buildings often use Portland mortar, making the brick hard to dismantle and clean. Cutting panels offers a unique tactile facades that carry patina and history into contemporary architecture.



Resource Rows © Lendager

Reused elements	Brick panel	Finish	Variable
New elements	x	Application	Cladding
Dimensions	Variable		
Load bearing	no	Feasability	●●●●○

Sources Lendager, Ressource rows.

14. Concrete Flat Stack

We developed this component based on an experimental project, proposed in the master thesis Rubble Rubble by Peer Neetke. He tested using flat sided concrete elements as pillars. In this thesis, we propose using these stacked elements as foundation columns, capitalizing on the irregular edges to create natural ground anchors and offering a robust, reusable structural solution that can be assembled with minimal modification.

Flat stack pillar © Peer Netke

Reused elements	Paralell flat sided concrete	Finish	Variable
New elements	Cement (binder)	Application	Pilars, foundation
Dimensions	Variable		
Load bearing	Compression based	Feasability	●●○○○

Sources Neetke, Rubble-Rubble.

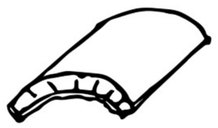
Basement in Gallery House

15. Rubble Barrel Vault

Barrel vaults have a long tradition as efficient load-bearing structures. Recent research by Christoph Gengnagel and Emil Brechenmacher has re-examined these forms with the aim of reducing CO_2 emissions by experimenting with alternative materials and construction techniques.

Building on this research, we explore the potential of incorporating rubble as a primary material in vaulted constructions. The concept draws on the compressive strength of rubble, repurposing it for a structural function where it performs best.

We have tested three full-scale prototypes using materials sourced from demolition sites in Trondheim, similar to materials found in the ruins of Irpin. The goal is to reduce the amount of new reinforcement (rebar) and cement required for slabs, while maximizing the use of reclaimed rubble within the structural system.



Kappe + vault © Emil Brechenmacher.

Reused elements	Reclaimed brick	Finish	Covered or exposed brick in ceiling
New elements	Wooden Beam, (steel rod)		
Dimensions	span: 5.4m alone or 6.75m with steel rod. width: 135cm	Application	Slab, ceiling
Load bearing	Compression based	Feasability	● ● ● ○ ○

Sources Gengnagel, Kappe+

Lamella Row Houses

15.1 Parallel Flat Sided Rubble Vault

Concept
This prototype explores the use of parallel flat-sided rubble elements in both primary components of a vaulted ceiling: the supporting beams and the vault itself. Large concrete sections, cut from a roof, act as beams spanning 3 to 6 meters, depending on the integrity and reinforcement of the concrete. The parallel flat sided rubble pieces form the vault between these beams.

Pros
The system minimizes the use of new cement, limiting it to mortar joints and potential connections between beams and the load-bearing structure. This significantly reduces cement demand compared to a conventional concrete slab.

Cons
This is a speculative system with no directly comparable precedent. Key concerns include unpredictable weight, variable material quality, and structural uncertainty. For example, using reused concrete with compressive strength B30 (120 mm thickness, 1.5 m width) would require beams approximately 1 meter high for a 6-meter span.

Reflection
A physical section of the vault was constructed to explore the idea and contribute to the ongoing discussion. The next step would be to conduct a structural feasibility study in collaboration with structural engineers. A potential refinement could involve exploring different landings for the arch. Despite challenges, this concept represents a potential for maximizing rubble reuse in structural components.

15.2 Prefabricated Rubble Vault

Concept
This test explores the casting of new precast arches using a high percentage of rubble as coarse aggregate. The reused angle steel provides an efficient and visually minimal landing compared to the bulkier concrete alternatives. The rubble-to-concrete replacement ratio (RR) was tested at approximately 50%, exceeding the typical 20% recommendation for recycled concrete aggregate (RCA). We assume that the compressive loads in arches allow for a higher content of rubble.

Pros
The method follows known construction techniques, making it more feasible compared to more experimental concepts. The use of recycled components reduces the demand for new concrete.

Cons
The weight of the precast units remains an issue. Future explorations could investigate incorporating voids or optimizing the thickness along the curve to minimize material use. Swapping rubble for hollow spaces could improve weight handling but requires further research.

Reflection
The prototype validates the idea of using rubble at a higher rate in precast arches. The next research step could be exploring optimized geometries and minimizing thickness without compromising structural integrity. The approach offers potential for combining rubble reuse with controlled manufacturing processes.

15.3 Reclaimed Brick Vault

Concept
Building on the research of Christoph Gengnagel and Emil Brechenmacher, this test applies sorted reclaimed brick as a vaulting material between timber beams. The model uses discarded bricks from construction sites in Trondheim, in order to explore their reuse potential in a load-bearing vaulted form.

Pros
The method offers a straightforward application of sorted brick rubble, expanding the possibilities of rubble vault construction with well known materials and techniques.

Cons
The main limitation is the labor intensity and time required for masonry construction compared to prefabricated systems. Performance depends heavily on the quality of reclaimed bricks and workmanship.

Reflection
This model served as a proof-of-concept for combining timber beams with a reclaimed brick vault. Further work should evaluate full-scale load-bearing capacity and develop practical design guidelines. The test illustrates how even small-scale brick rubble can be meaningfully integrated into structural elements.

2.4 BUILDING SYSTEM

This chapter provides an overview of where the different components appear in the building system.

System overview

Building systems is defined as a combination of building components, creating a complete system for building construction. When used in construction, all prior components can be represented as a part of this system. This section is made to function as an overview of the different possibilities and variations for the components within this system.

The system is divided into the following categories, based on their structural appearance in the system:

2.4.1 Walls
2.4.2 Slabs
2.4.3 Cladding
2.4.4 Foundation
2.4.5 Roof
2.4.6 Insulation

Each part of the system variations are given the following properties:

Components options: the main component(s) used in the system.

Additions: other added elements, components or building systems, making the system functionally complete.

Plan: Diagram of proposed plan for the system.

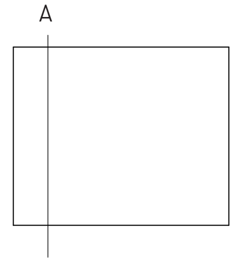
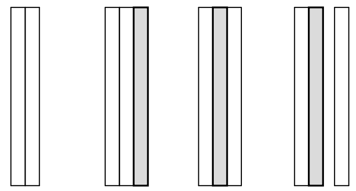
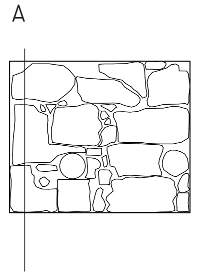
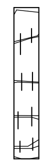
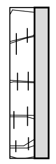
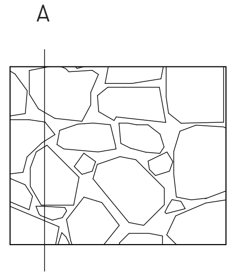
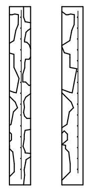
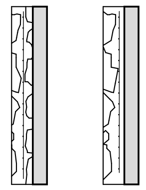
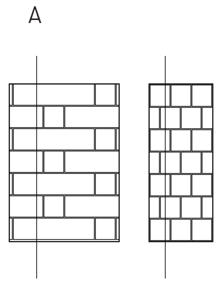
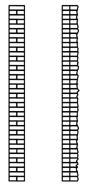
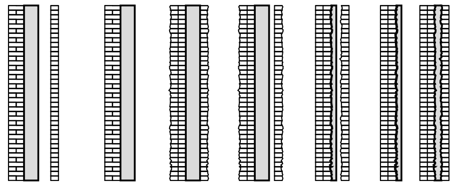
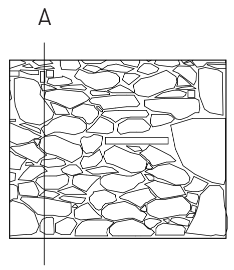
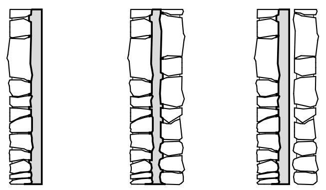
Section AA: Diagram of proposed vertical section.

Section BB: Diagram of proposed horisontal section.

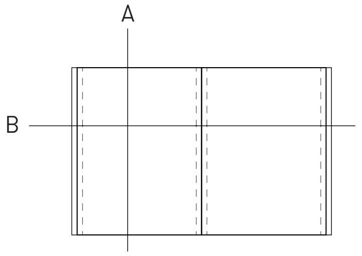
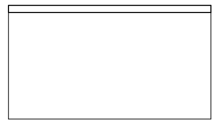
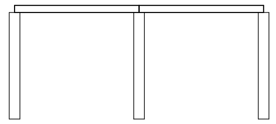
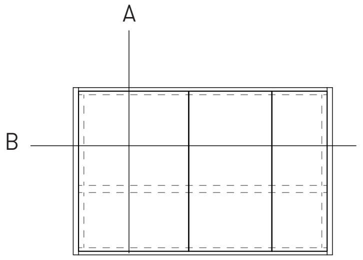
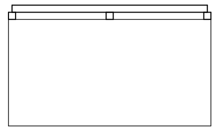
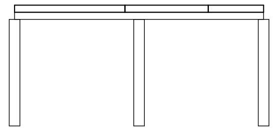
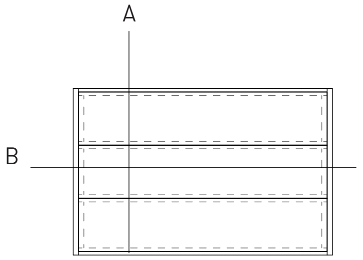
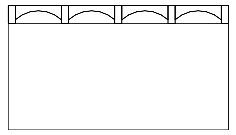
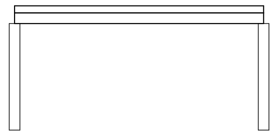
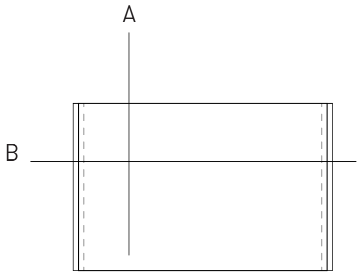
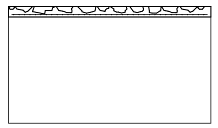
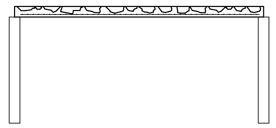
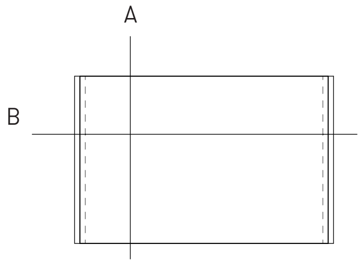
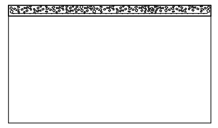
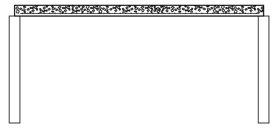
Notes: Reflections on possible usage and limitations of the system.

Sources and references: research and references on same or similar systems.

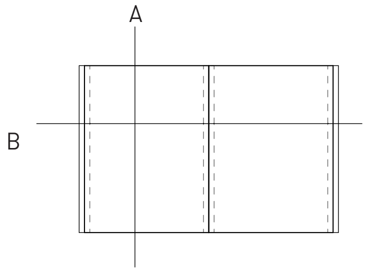
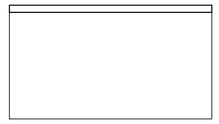
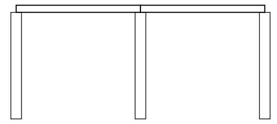
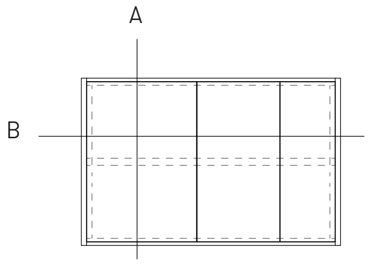
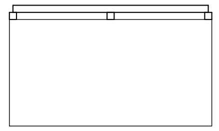
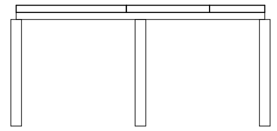
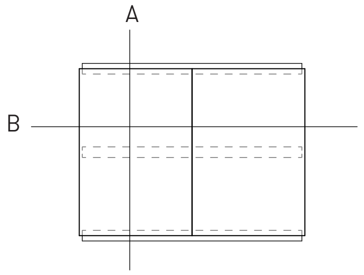
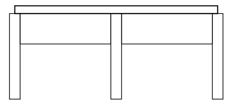
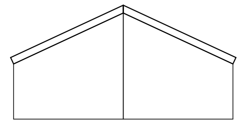
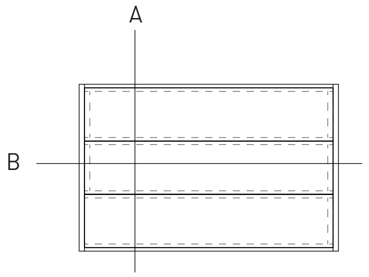
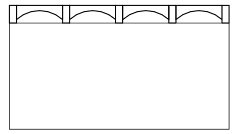
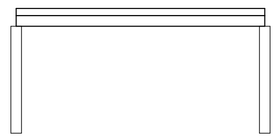
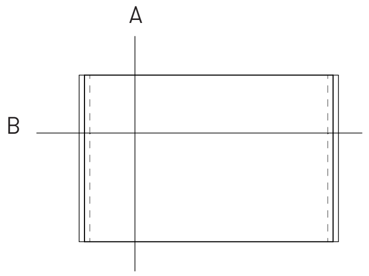
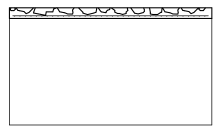
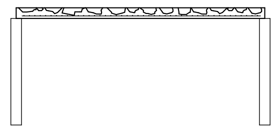
2.5.1 Walls

Name	Components	Additions	Elevation	Section A	Variations	Notes	Sources
1. PRECS Wall	2. PRECS wall	Joints: metal brackets				Can be sandwiched wilh pressure resistant insulation. Condition will vary depending on source and must be tested per instance.	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
2. Single leaf rubble wall	6. single leaf rubble	As partition wall: insulation, inner cladding.				Made standing	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
3. Large rubble wall	10. Large rubble concrete	Joints: metal brackets				Made flat and then raised. Can be single- or double-sied.	Fabel, Viksjø, naturbetong.
4. Rubble brick wall	9. Rubble masonry	Joints: metal rods				Example of bond options preferable for damaged brick: english bond, header bond, rowlock bond.	Skat, Perspectives of Urban Mining
5. Rubble masonry wall	9. Rubble masonry	Joints: metal rods				Masonry technique must be adapted to availible materials. See appendix for different options suitable for rubble.	David Chipperfield Arhitects, Rubble-Works.

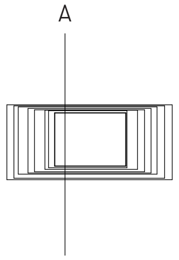
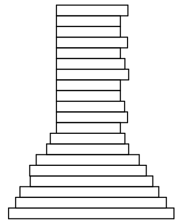
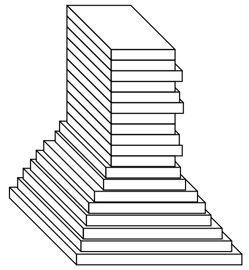
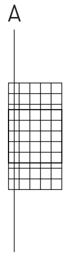
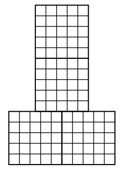
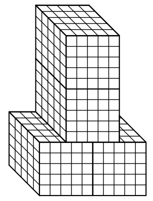
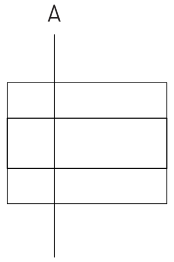
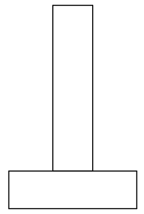
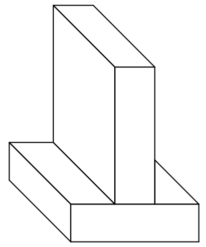
2.5.2 Slabs

Name	Components	Additions	Plan	Section AA	Section BB	Notes	Sources
1. PRECS Slab	2. PRECS slab	Joints: metal brackets				Beams spanning between load bearing walls, with PRECS slabs spanning between beams. Allows for reuse of smaller and Irregular PRECS elements. Can be laid double if structurally needed.	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
2. PRECS + Beam	2. PRECS slab	Insulation: Flooring:				Beams spanning between loacl bearing walls, with PRECS slabs spanning between beams. Allows for reuse of smaller PRECS components. PRECS can be laid double if structurally needed.	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
3. Rubble vault slab	15.1-15.3 rubble vault	Beam Distribution:				Allows for longer spans from rubble elements.	Gengnagel, Kappe+
4. Large rubble slab	10. Large rubble concrete	-				Allows for longer spans from rubble elements. One flat sided rubble is prefered	Viksjø, naturbetong. Wright, Taliesin West.
5. RCA Slab	7. Rubble Aggregate	-				Same construction technique as regular concrete, with 20% replacement ratio. Tested in 15.2 arch with 50% replacement ratio.	Ajayebi, Optimal Replacement Ratio of RCA

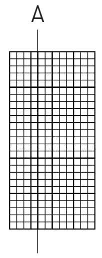
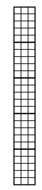
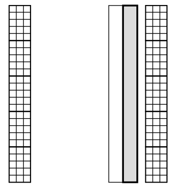
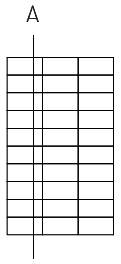
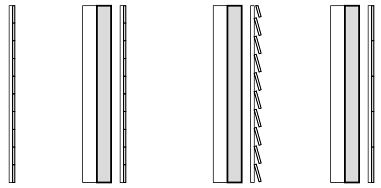
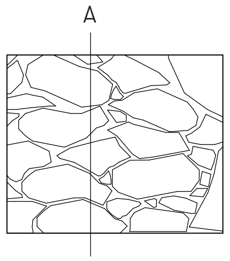
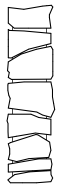
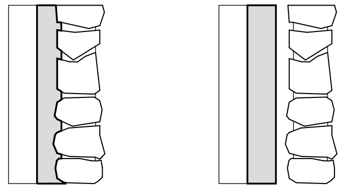
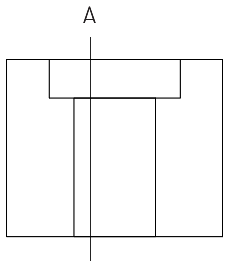
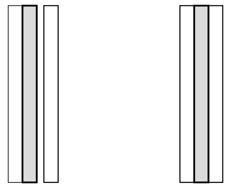
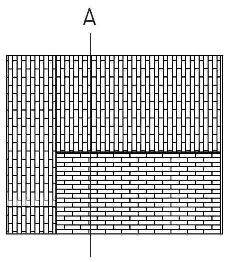
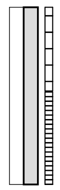
2.5.3 Roof

Name	Components	Additions	Plan	Section AA	Section BB	Notes	Sources
1. PRECS Flat roof	1. PRECS slab	-				Must be slightly slanted for water drainage. Can be done through slanting the slab or slanting a secondary construction on top.	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
2. Supported flat PRECS	1. PRECS slab	-				Must be slightly slanted for water drainage. Can be done through slanting the slab or slanting a secondary construction on top.	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
3. Slanted PRECS roof	1. PRECS slab	-				PRECS can be cut as a triangle gable to function as a support construction.	Asam, urban renewal.
4. Rubble vault ceiling	15.1-15.3 rubble vault	-				Must be slightly slanted for water drainage. Can be done through slanting the slab or slanting a secondary construction on top.	Viksjø, naturbetong. Wright, Taliesin West.
5. Large rubble ceiling	10. Large rubble concrete	-				Must be slightly slanted for water drainage. Can be done through slanting the slab or slanting a secondary construction on top.	Ajayebi, Optimal Replacement Ratio of RCA.

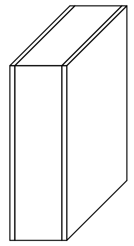
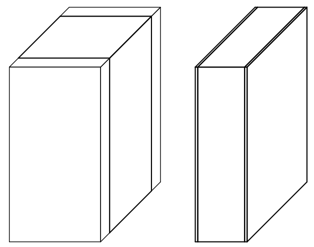
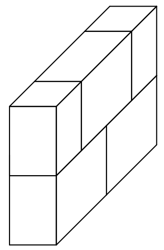
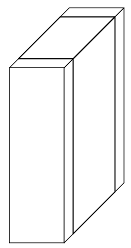
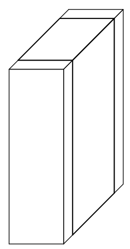
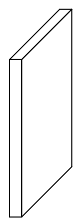
2.5.4 Foundation

Name	Components	Additions	Plan	Section AA	Axonometry	Notes	Sources
1. Concrete flat stack foundation	14. Concrete flat stack	-				Irregular edges to create natural ground anchors. Wider lower part for stability.	Neetke, Rubble-Rubble.
2. Gabion point foundation	5. Gabion	-				Can function as drainage.	Neetke, Rubble-Rubble.
3. RCA Foundation	7. Rubble aggregate	-				Using same approach as regular concrete.	Ajayebi, Optimal Replacement Ratio of RCA.

2.5.5 Cladding

Name	Components	Additions	Plan	Section A	Variations	Notes	Sources
1. Gabio cladding	5. Gabion	Steel frame or mounting brackets.				Can also function as drainage.	Asplan Viak, Mulighetsstudie. Küpfer, Reuse of Concrete Components
2. Terrazzo cladding	11. Rubble Terrazzo	Steel frame or mounting brackets.				Regular panel cladding approach.	Rubblazzo, Rubble terrazzo.
3. Rubble masonry cladding	9. Rubble masonry	Veneer tie				Using any masonry technique. See appendix for different options suitable for rubble.	David Chipperfield Arhitects, Rubble-Works. Skat, Perspectives of Urban Mining.
5. PRECS cladding	3. PRECS non-load bearing wall	Steel frame or mounting brackets.				Requires proper fixing between panels.	Küpfer, Reuse of Concrete Components
5. Brick panel cladding	13. brick panels	Steel frame or mounting brackets.				Requires proper fixing between panels.	Lendager, Reesource Rows.

2.5.6 Insulation

Name	Elements	K-Value	Section AA	Pressure resistance	Notes	Sources
1. EPS Panels	27. Expanded polysterine	0.033		Moderate	Often used as external insulation. Can be dismantled and reused.	Terraco Group, U-Values.
2. Straw (bale or panels)	21. Straw 24. Wood framing	0.06		Low	Can be made from byproduct of agricultural waste.	Straw Works, Thermal Conductivity of Strawbale.
3. Hempcrete blocks	19. Hemp	0.06-0.07		Moderate	Can also be used for construction purposes.	OzHemp, Let's Talk About Hempcrete.
4. Hempwool	19. Hemp	0.04-0.06		High	-	Insulation, Ultimate Guide to Insulation Values.
5. Wood fibre	29. Wood fibre	0.036-0.038		Low	-	STEICO SE, Environmental Product Declaration
6. Mycelium panels	17. mycelium 2. fine rubble	0.029-0.104		Moderate	-	Khaled, Evaluating Mycelium.

2.5 REFLECTIONS

Thoughts, learnings and summary of the material catalogue.

Reflections

The material catalogue does not offer final answers, but explores and map possibilities of reuse in Ukraine. Some of the strategies we propose are already feasible and tested, while others are more speculative.

A central aspect has been the comparison between PRECS components (reused building elements from dismantled I-464 typologies) and rubble components (new architectural components made from rubble). The PRECS components offer predictability. They benefit from a highly systemized production, making dismantling and reuse technically viable. However, they also come with clear dimensional constraints, which heavily influenced our proposed building system and the pilot typologies.

The rubble components on the other hand presented a more open-ended challenge. The inconsistent nature of rubble pushed us toward experimental thinking, grounded in the materials characteristics. We drew from historic methods of reuse, such as rubble masonry and spolia, as well as contemporary experimental research and references. Our approach was to investigate how we could benefit from the material's properties and combine them into new components. In this sense, we adopted and extended Louis Kahn's philosophy—"You say to a brick, 'What do you want, brick?'"—by asking: "What do you want, rubble?"

This question became the core of our methodology for the rubble components: exploring how rubble can define its own architectural potential. Benefitting from the high volume of rubble in gabions, using parallel flat sided rubble in arches and flat stacks, and exploring the aesthetic and symbolic value in terrazzo and masonry facades.

Together these components form a speculative toolkit, presented as a complete building system. This lays the groundwork for the next step: translating the material potentials into architecture, presented in the next folder: 03 Pilots.

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Title
Rising from Ruins: Rebuilding in Ukraine

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