Remezclando nuestras ciudades: investigación reciente sobre la circularidad en el sector de la construcción

Remixing our cities – current research on circularity in the construction sector

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Abstract: The European Green Deal is aiming for a transition from the current linear economic model to a much more sustainable and resource-efficient circular model. Since the construction industry is responsible for 37% of Europe-wide waste, it will be a key sector for the successful implementation of this goal. However, we can currently find many sector-specific challenges slowing the pace. On the one hand, the complexity of the sector and the multiplicity of actors involved. On the other hand, the dichotomy between the immanent uncertainty that lies within all reuse strategies and an ever-rising pressure for an increased technical performance respectively liability exclusion of building components. A successful transformation of the construction industry towards a circular economy would hence require changes throughout the whole life cycle of the building stock, an extensive and comprehensive exchange of information and the implementation of strategies for dealing with uncertainties. This includes also the development of new construction standards, which in turn can be expected to have an influence on the resulting architectural design. The focus of this paper is to present two current research projects on these topics, with a focus on the potential implications and future fields of action for designing architects.

Keywords: circularity; urban mining; re-use; standardisation; detailing.

Resumen: El objetivo del Pacto Verde Europeo es la transición del actual modelo económico lineal a un modelo circular mucho más sostenible y eficiente en el uso de los recursos. Dado que el sector de la construcción es responsable del 37% de los residuos de toda Europa, será un sector clave para el éxito de la aplicación de este objetivo. Sin embargo, actualmente podemos encontrar muchos retos específicos del sector que ralentizan el ritmo. Por un lado, la complejidad del sector y la multiplicidad de actores implicados. Por otro lado, la dicotomía entre la incertidumbre inmanente que subyace en todas las estrategias de reutilización y una presión cada vez mayor por un mayor rendimiento técnico respectivamente la exclusión de responsabilidad de los componentes de los edificios. El éxito de la transformación de la industria de la construcción hacia una economía circular requeriría, por tanto, cambios a lo largo de todo el ciclo de vida del parque de edificios, un amplio y exhaustivo intercambio de información y la aplicación de estrategias para hacer frente a las incertidumbres. Esto incluye también el desarrollo de nuevas normas de construcción, que a su vez cabe esperar que influyan en el diseño arquitectónico resultante. El objetivo de este artículo es presentar dos proyectos de investigación actuales sobre estos temas, centrándose en las implicaciones potenciales y los futuros campos de acción para profesionales de la arquitectura y el diseño.

Palabras clave: circularidad; explotación urbana; reutilización; normalización; detallismo.

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INTRODUCTION

The reuse of architectural fragments in new constructions is probably as old as the building practice itself. Either for pragmatic reasons (transportation and crafting of materials used to be expensive and time-consuming) or serving aesthetic or ideological purposes (the so-called *Spolia*), the architectural fragments could be either transported directly from the demolition site to the construction site or stored intermediately in a depot until a new destination was found. This practice continued throughout the Middle Ages and the Renaissance period, when buildings that could not be adapted to modern uses "could be treated as quarries and torn apart in order to reuse their building materials" as a way to keep pace with the steady process of urban transformation.[1] However, this practice almost disappeared from the dominant architectural discourse presumably due to the arrival of the industrialisation (as both production and transportation became substantially cheaper and more manageable) and modernity's fascination for the new building materials (steel, glass, concrete). A pragmatic use of construction debris can be found again in the context of the post-war reconstruction,[2] as resources were scarce and rubble abundant. Otherwise, most examples of the reuse of reclaimed materials outside the context of monument protection during the late modernity were either a symbolic act,[3] or a means to achieve a stronger link to the local identity.[4]

While scarcity is currently not yet an issue, there is a renewed interest within the profession in the use of reclaimed materials, this time in the context of an increasing ecological concern and consequently a more conscious approach to resources. Outside the profession, regulation and policies like the European Green Deal are aiming for a transition from the current linear economic model to a much more sustainable and resource-efficient circular model as well. Two key points within this strategy are "defining national and municipal waste management policies" and "preparing circular economy strategies and action plans."[5] Since the construction industry is responsible for 37% of Europe-wide waste,[6] it will also be a key sector for the successful implementation of these goals. Therefore, an increasing pressure towards the implementation of re-use strategies on an unprecedented scale can be expected and we can already recognise some first initiatives and pilot projects exploring the potential in this field, as some architects and collectives have been thinking lately about what and how to build with discarded materials and elements and a considerable number of platforms and warehouses have emerged to that effect.[7]

However, one sector-specific challenge is the multiplicity of actors involved: from city planners, architects, engineers, and building companies to politicians, lawyers, data scientists, geographers and many other professions reaching beyond the construction sector itself. As a consequence, some of the first projects to face such an immense task were led by municipalities, like Stockholm's Hammarby Sjöstad metabolic model (1998-2004) and Zürich's "Bauwerk Stadt Zürich" (2004-2009). While Hammarby Sjöstad pursued the implementation of urban symbiosis[8] strategies, following a metabolic approach and therefore focusing on the circular flow of energy, waste and water,[9] "Bauwerk Stadt Zürich" focused on the life cycles of building material waste and has led to some implemented guidelines, like the increased use (up to 100%) of recycled concrete in public buildings,[10] turning the existing stock into an important alternative source of gravel for the future.[11]

Considering the complexity of establishing a circular economy in the construction industry, the objective of this paper is to present two current research projects to illustrate the variety of issues involved, existing dependencies, main problem areas and some possible approaches towards solutions.

CITY REMIXED – A CASE STUDY

The *City Remixed* project was one of the first steps to open the way for the implementation of circularity within the construction industry in the city of Graz,

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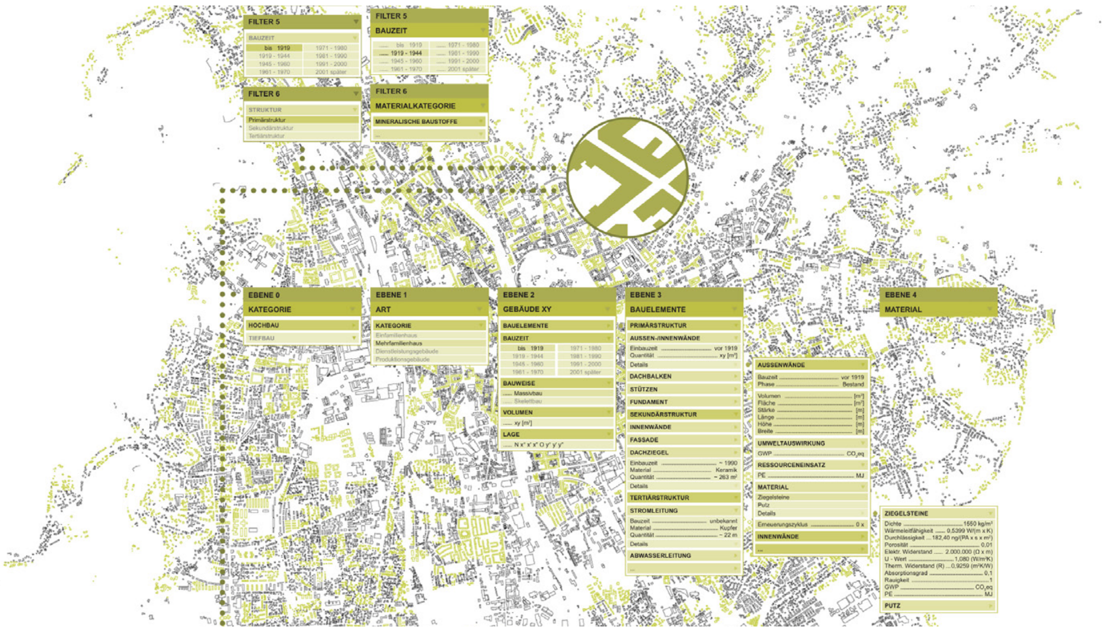

Figure 1. Example of a possible data structure for such an enhanced geo-referenced documentation of Graz's building stock.

Austria. Within this project, a multidisciplinary team led by architects examined the urban and peri-urban area as a closed system. This meant testing different methods for documenting the prototypical "Graz building stock" (including its spatial and temporal attributes) in order to obtain a digital inventory of the built substance and enrich it with metadata to make it accessible for further use, as well as analysing the standard processes of demolition, the current reuse and recycling options for building components and single-material debris, the existing facilities for their processing within the city's and its surroundings and other topics of logistics and resource distribution based on the development of potential scenarios. The exchange with experts from different areas, companies and authorities was key in order to manage such complexity.

The findings were presented as seven fields of action, decision-making bases and recommendations:[12]

1. Knowledge of the available building resources
2. Planning and project development
3. Circular construction
4. Reuse-oriented deconstruction
5. Processing and manufacturing
6. Logistics and construction resource exchange
7. Legal framework and incentive schemes

KNOWLEDGE OF THE AVAILABLE CONSTRUCTION RESOURCES

Having reliable data on potentially available building resources and the status of their availability is highly relevant for relevant to establish a circular economy. However, this information is currently either lacking, or distributed along different, often not interconnected databases like municipal geo-information systems,[13] 3D city models, building and housing registers and diverse archives. This is aggravated by the fact that an exhaustive survey of the existing building stock is a highly complex and laborious task, as detailed information on inbuilt components (e.g. static parameters, component specifics) can hardly be determined

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retrospectively.[14] Data protection or commercial reasons may also impede access to this information,[15] as there is a lack of legal clarity about how and which data should be handed over to the municipalities.

A first approach to counteract these challenges would be the documentation of the existing building stock through the classification of building elements into a primary (load bearing elements), secondary (fillings, thermal and vapor control etc.) and tertiary (finishes and HVACR) structure[16] in combination with BIM - Building Information Modelling. A representative number of construction analyses could then be extrapolated to the whole city using statistic data[17] on the basis of the "ARK-Haus method". In this method, buildings are categorised into four types of use and four time periods, and each category is assigned different statistical material-specific average values for each time period.[18]

A temporal allocation including geo-referencing of the buildings could similarly be possible through photogrammetric analyses, inspections, urban morphology (eventually enhanced through machine learning) and on the basis of existing GIS data.[19] The data structure for existing and new buildings and infrastructure networks could be based on "Material Passports,"[20] the "Building Passport" respectively "Infrastructure Building Passport" or,[21] in line with recent European endeavours, the "Digital Building Logbooks."[22]

PLANNING AND PROJECT DEVELOPMENT FOR CIRCULAR CONSTRUCTION AND REUSE-ORIENTED DECONSTRUCTION

While practicing architects are at least tangentially present in all the previously named seven fields of action, their contribution is key for number *2 - Planning and Project Development* and *3 - Circular Construction*, as the decisions taken during the design will influence the potential for circularity of our building stock to an extent that cannot be reached by later measures. While the potential for the disassembly of building components does not necessarily result in a circular building, it is widely regarded as a prerequisite for achieving circularity. The concepts of "Design for Disassembly" and "Design for Recycling"[23] or "Reversible Architecture,"[24] which are characterised by dismantling methods and non-destructive detachability, are particularly noteworthy here. Buildings that are designed for circularity thus require an appropriate design of the constructive interfaces between components of different function and use, between short-lived and long-lived elements, as well as between materially heterogeneous building components.

The distinction in primary, secondary and tertiary structural layers enables elements with a shorter lifespan to be individually replaced without causing damage to more permanent elements. This means on one hand avoiding bonding connections,[25] and striving instead for hanging, laying, clamping, screwing[26] or even hook-and-loop connections.[27]

While some implemented pilot projects have taken this point up and work on design-kits that can be disassembled and reassembled, this is currently still the exception, as today's construction standards generally produce buildings that cannot be selectively dismantled. In order to provoke the necessary cultural shift in the construction sector and consequently to have a noticeable impact in terms of climate change mitigation we need scalability: to jump from the particular to the standard, from the exception to the rule. And as so often, the devil - but also the solution - seems to be in the details, specifically in the standard construction details.

Noadays, standardized design catalogues set the basis for the construction practice, as they prioritize design, technical production and legal issues on which a project can be further developed. They are chosen at a relatively early stage of the design process? Thus setting the underlying system definition for the project. These catalogues are the result of many years of experience but they constantly evolve to follow changes in regulations

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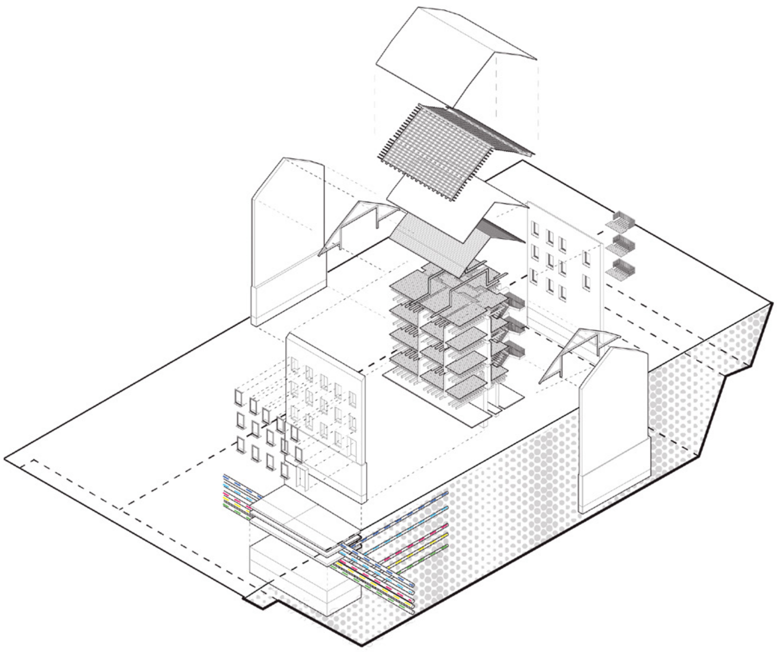

Figure 2. Systematic identification of layers of an existing building.

and/or implementation of new technologies. In order to stimulate and facilitate their evolution towards a circular model and by doing so, identify their challenges and potential for further development, the research project "Circular Standards" was born.

Within the project, eighteen standardized construction details were chosen based on their current relevance within the building practice in Austria and their common acceptance in both a theoretical (regulations) and a practical (supplier manuals) level. The selected detail drawings were then evaluated with regard to their ability to deconstruct. The focus was set on the constructive joint, considering the used technologies, dependencies among the surrounding layers and the accessibility of the connection itself, following the "Disassembly potential measurement" method.[28] Subsequently, the details were redesigned, examined and analysed by the research team together with extern experts, in order to identify problems in dismantling and to elaborate potential adjustments that would allow the replacement of individual parts without destroying or altering the building components to an unacceptable extent.

As an example, we can see in the parapet detail (Figure 3) that both the waterproofing (5) and vapor barrier (3) form a tight seal, thus turning all elements in between into a non-deconstructible package. Replacing the chemical bond with mechanical fastening is obviously not an option here, so the next strategy was to limit the connection to building layers with similar life expectancy. As seen in Figure 4, the vapor barrier (3a) was hence fixed onto the concrete slab (1) and only glued along the perimeter in order to reach enough tightness. Thereby, it could be possible to detach the vapor barrier by just cutting off the perimeter and still reuse most of this layer. The same strategy was tested for the waterproofing layer (5a), (7a), (15a).

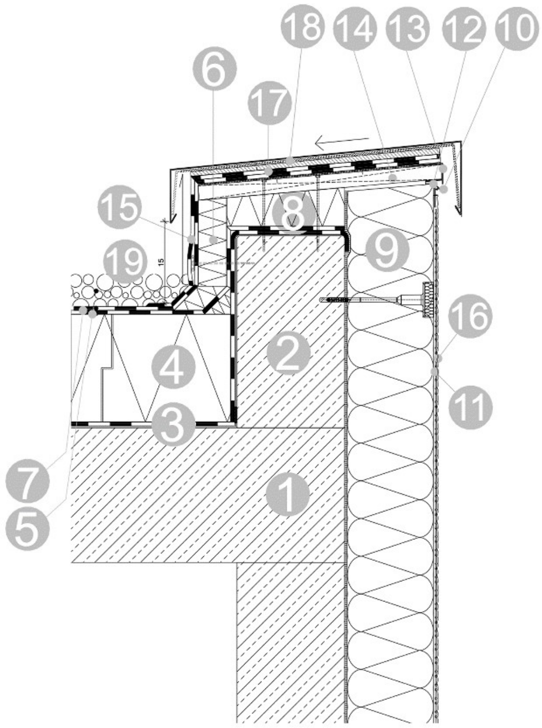

Figure 3. Standard Austrian flat roof parapet with ETICS facade detail.

Caption: (Nr) structural layer - component - connection.
(1) & (2) primary - reinforced concrete slab and parapet - poured in-situ / monolithic
(3) secondary - vapor barrier - glued
(4), (6), (8) & (9) secondary - thermal insulation - glued and mechanically fastened
(5), (7) & (15) secondary- waterproofing, 2-ply - welded or glued
(10) secondary - plaster edging - mechanically fastened
(11) secondary - reinforcing mesh - cementitious connection
(12) secondary - water stop seal - glued
(13) secondary - drip edge - mechanically fastened
(14) secondary - wooden board - mechanically fastened
(16) tertiary - exterior plaster - cementitious connection
(17) & (18) tertiary - parapet capping and sheet metal clip - mechanically fastened
(19) tertiary - gravel - loosely laid.

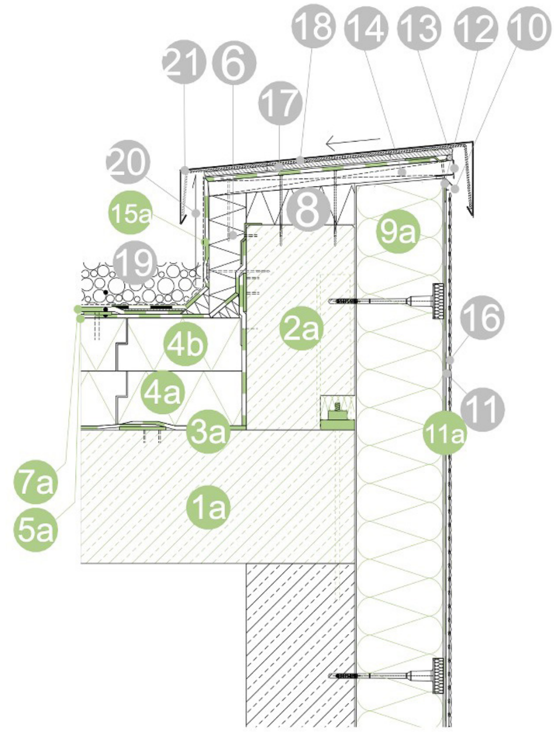

Figure 4. Deconstructable version of the previous detail.

(1a) primary - reinforced concrete slab - poured in-situ / monolithic
(2a) primary - reinforced concrete parapet - prefab - screwed connection
(3a) secondary - vapor barrier - glued at the perimeter; fastened to (1a)
(4a), (4b), (9a) secondary - thermal insulation - mechanically fastened
(6) & (8) secondary - thermal insulation - glued (temporary) and mechanically fastened
(5a), (7a) & (15a) secondary - waterproofing, 2-ply; bonded at perimeter; fastened to (1a) (4b)
(10) secondary - plaster edging - mech. fastened
(11a) secondary - disassembly mesh - pin/screw connection to (9a)
(11) secondary - plaster - cementitious connection to (11a)
(12) secondary - water stop seal - glued
(13) secondary - drip edge - mech. fastened
(14) secondary - wooden board - mech. fastened
(16) tertiary - exterior plaster - cementitious connection
(17) & (18) tertiary - parapet capping and sheet metal clip - mechanically fastened
(19) tertiary - gravel - loosely laid.

However, we are well aware that the contradictions between the intrinsic requirements of tightness and the potential disassembly of the layers shown in this example cannot be solved alone through pure technical aspects but require a more in-depth analysis that also includes architectural (e.g. roof type), legal (regulations, liability, etc.) and many cultural (expectations, commitment to maintenance, perception of aging, etc.) issues.

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PROCESSING, MANUFACTURING AND LOGISTICS FOR AN EFFECTIVE CONSTRUCTION RESOURCE EXCHANGE

It is also due to cultural values, that some objects (e.g. historic doors, tiles and windows) are already somehow within a circular economy, while other dismantled building components that no longer meet current "cultural" trends are still lacking acceptance in the sector and prone to downcycling.[29] However, in order to achieve circularity and significantly reduce the raw materials supply chain, the downcycling of building components must be avoided and stay within their performance level during their successive cycles, which in turn needs standardised technical specifications, as seen in the previous chapter.

A key instrument here is the testing and evaluating of the dismantled components: starting with preliminary testing of their accessibility and dismantling options, followed by a visual assessment plus technical sample testing of the components and complemented by monitoring changes in their condition following transport, handling, storage, etc. Such an increase in testing and processing activities of dismantled building components needs a certain local or regional network with a large number of laboratories, service providers and relevant skilled companies. In a mid-term scenario, it can be expected that circularity will allow more control over labour conditions,[30] and strengthen local economies.[31] In a short-term scenario though, economic efficiency cannot be yet reached without monetary incentives and subsidies that encourage the emergence of new business models and the reorientation of existing companies. At a municipal level, a consequent implementation of policies is needed - for example, by making urban areas readily? Available for the storage, processing, and classification/certification of dismantled components.

In terms of logistics, the current exchange platforms for dismantled building resources have a limited offer and demand a relatively high effort from users. Consequently, they are primarily aimed at private individuals and cannot yet supply on a large scale. In order to achieve efficient solutions for the storage of dismantled building resources, the knowledge of "what" has to be transported in "what quantity" and at "what time" is key,[32] which brings us back to the necessity of proper databases and planning software for the transfer of information about (future) reusable construction resources. For this purpose, databases that cover a certain area can be linked directly to the software via BIM. The time offset between planning and actual installation, and therefore time for storage and/or preparation, plays a key role here. Another possibility worth exploring is linking the places for the storage and sale of reuse material (the so-called architectural salvage centers) with the planning software itself.[33]

LEGAL FRAMEWORK AND INCENTIVE SCHEMES

As mentioned in previous chapters, legal aspects play an important role in establishing a circular economy, as legal ambiguities and/or contradictions can discourage the reuse of building components even in cases of optimal technical condition. While there are many relevant legally binding regulations - from EU regulations to national laws - some of them are not clearly linked or even contradict each other. But not only laws and regulations have to evolve in order to catch up with the times, new protocols are also needed for various process steps (dismantling, analysis, processing, storage, etc.). As a result, a clearer legal framework would definitely increase the confidence of building professionals and insurance companies in reusing strategies and mitigating the friction between the ever-rising pressure for an increased technical performance (respectively liability exclusion) of building components and the immanent uncertainty that lies within all reuse strategies. On a positive note, both the international standardization organization ISO, as well as the European Standardization Strategy are currently addressing the topic of circular economy in their work,[34] so it can be expected that the legal situation will change throughout Europe, at least in the mid-term.

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A further important aspect are legislated incentives, subsidies and penalties, but to be effective, they have to be implemented throughout the whole system in a coherent manner. For example, if a national agency states "use of recycled aggregate" in a certain proportion for concrete as a positive criterion for sustainability, then the corresponding Public Procurement Act should not penalize the corresponding cost increase in public bidding.

CONCLUSION

While we still have a long way to go, there is a growing development of circular economy strategies in the construction sector that might lead to deep changes within the sector in the upcoming years. We can observe that, in spite of their distinct territorial contexts, many similar initiatives are currently rising within Europe in order to encourage and install reuse in the construction sector.

While individual solutions are an interesting field of experimentation, real change can only be achieved through scalable measures – standardisation is therefore key. We see here a great potential in both the increasing digitalisation of the sector and the standardisation of detachable joint solutions. In addition, it is also necessary to ensure consistency with other ambitions in terms of social sustainability, protection from toxic agents, energy performance of buildings, etc. However, real changes will require a deep cultural redefinition of our societal set of values as well.

Summing up, radical new approaches are required to redirect society away from the depletion of raw materials, mismanagement of our limited resources and the throwaway mentality and toward goals of equilibrium rather than uncontrolled growth.

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2 Individual elements such as beams, fireplaces, wash basins and pipes used to be collected and reused. The remaining mineral debris was mostly reused to fill bomb craters and trenches or as aggregate for the brick and concrete industry.

3 E.g. Godfried Böhm's use of fragments of the bombed Kolumba church in his chapel of Madonna in the Ruins in Cologne (Germany).

4 E.g. Rudolf Olgiati's reuse of handcrafted parts from demolished buildings in order to create a lively relationship with the past in his houses in Graubünden (Switzerland) during the 1970s.

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6 "Generation of waste by economic activity (2004-2020)," Eurostat, last update: 14/06/2024 23:00, https://ec.europa.eu/eurostat/databrowser/view/ten00106/default/table?lang=en.

7 Architects like Superuse Studios (Rotterdam), Rotor (Brussels), baubüro in situ (Switzerland) and Lendager Circular Advising (Copenhagen) and a long etc.; platforms and consulting firms like Encore Heureux (Paris), Studio Assemble (London), Materialnomaden (Vienna), Madaster Foundation (Amsterdam), Concular UG (Stuttgart) etc. and even architectural festivals like Bellastock (Paris).

8 Defined here as "the use of by products (waste) from cities (or urban areas) as alternative raw materials or energy sources for industrial operations." 110113253

9 Sofie P. Iveroth, "Industrial ecology for sustainable urban development - the case of Hammarby Sjöstad" (PhD-Thesis at KTH. Universitetsservice US-AB, Stockholm, Sweden, 2014). ISBN 978-91-7595-123-2.

10 The recycled concrete used here has a minimum recycled aggregate content of 50% for structural concrete and 80% for filling, cladding and base concrete. However, an associated problem with the use of recycled concrete as aggregate is that a higher cement proportion is needed, thus relativizing its positive environmental impact.

11 tefan Rubli, Annick Lalive d'Epinay and Philipp Noger, "Ressourcenstrategie „Bauwerk Stadt Zürich",“ *Müll und Abfall*, no. 10 (2014), https://doi.org/10.37307/j.1863-9763.2014.10.06

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13 E.g. since a building permit only grants the right to build or modify something within a certain period, there is no obligation to implement this permit at all. In addition, much of the existing historical data of our cities is not digitised or georeferenced.

14 "Instrumente zur Wiederverwendung von Bauteilen und hochwertigen Verwertung von Baustoffen," Umwelt Bundesamt (Ed.), http://www.umweltbundesamt.de/publikationen/instrumente-zur-wiederverwendung-von-bauteilen

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