Manual of Recycling

Buildings as sources of materials

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Anja Rosen
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Edition DETAIL

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Contents

Eco-Efficient Construction Using Local Resources

Thomas Matthias Romm, Thomas Kasper

Resources on the Building Site, the Genius Loci

Controlling flows of materials in construction is an essential activity in the context of environmentally effective, cost-efficient building materials and construction site logistics. In the past 20 years, demand for mineral building materials worldwide has tripled [1]. Secondary raw materials, i.e. materials obtained through recycling, can meet only part of this demand. These materials cannot solve resources problems, but they could contribute to a solution. 80 % of the materials needed to construct a building are required for earthworks and the building's shell. Excavated earth, for example, is usually removed from building sites. In Germany only some of this excavated earth has to go into landfill; 75 % of it can potentially be utilised. Sand, gravel and concrete usually arrive at building sites after being transported over an average distance of 15 to 30 km. In many cases, sandy gravel from excavated earth could be turned into aggregates for concrete on-site without much effort.

Major construction projects clearly reveal the increased added value of on-site raw materials production in construction. The building of railway stations, highways and tunnels requires efficient materials logistics that aims to optimise supply and disposal by means of processing and balancing earthworks. This demands both precise planning of materials flows and management of their logistics on site.

Analysis instruments and measures

Logistics planning for the use of local resources in construction management materials flows is based on an analysis of the materials' qualities. A survey of pollutants and impurities assesses the permissible reuse of materials resulting from a demolition before a construction project starts and the geotechnical survey reports and survey reports required by laws on waste regulate the use of excavated earth. Soil classification for construction purposes as defined in DIN 18196 determines the extent to which soil can be used as a building material. Local use of excavated earth minimises landfill volumes, preserves resources extraction sites, and greatly reduces heavy vehicle traffic.

Soils that are less valuable for construction purposes can also be included in planning in the form of balancing earthworks. Backfilling and terrain modelling in open spaces often offer possibilities for a predictive mass balance, although this is frequently not possible without further processing for cohesive soils and nutrient-rich topsoils. Here, crushed brick and other lightweight water-retaining aggregates (e.g. expanded clay or aerated concrete) from a demolition can be used to optimise the properties of soils. Recycled materials, used on green roofs, for example, can improve the resilience of residential areas in coping with the effects of climate change such as global warming and torrential rainfall events by enhancing the soil's ability to retain water. Laying this kind of vegetation substrata reduces rainwater discharge and can be part of decentralised flood protection measures. These kinds of green spaces also make urban areas more resilient in long, dry periods.

Building materials recycled on-site have a more positive impact in a life cycle assessment than primary raw materials, because they do not need to be transported. This makes recovery-oriented dismantling before a construction project begins an important factor in the successful strategic planning of resource use with processing infrastructure on the building site (Fig. A 6.2).

Materials from the dismantling of buildings and site soil can be regarded both as raw material deposits on a building site and as part of the "genius loci", so on-site processing and balancing earthworks are crucial instruments in sustainable mass flow management.

The EU Waste Framework Directive defines excavated earth that is reused on site as "not waste", unlike excavated earth that is removed from a building site. This has a range of legal consequences (see "The Legal Background", p. 16ff.), so using excavated earth on the site it has been extracted from also has advantages in terms of compliance with waste management legislation.

For some years, this fundamental knowledge has been successfully put into practice in large-scale construction projects in Vienna, one of Europe's fastest growing cities.

A 6.1 Start of construction work in 2014 in Aspern Seestadt, Vienna showing building materials processing on site.

A 6.2 Circular economy on a building site: Construction that dispenses with large-scale soil excavation (waste reduction), reuse of structural components and recovery and recycling of building materials sourced on the building site (on-site recycling)

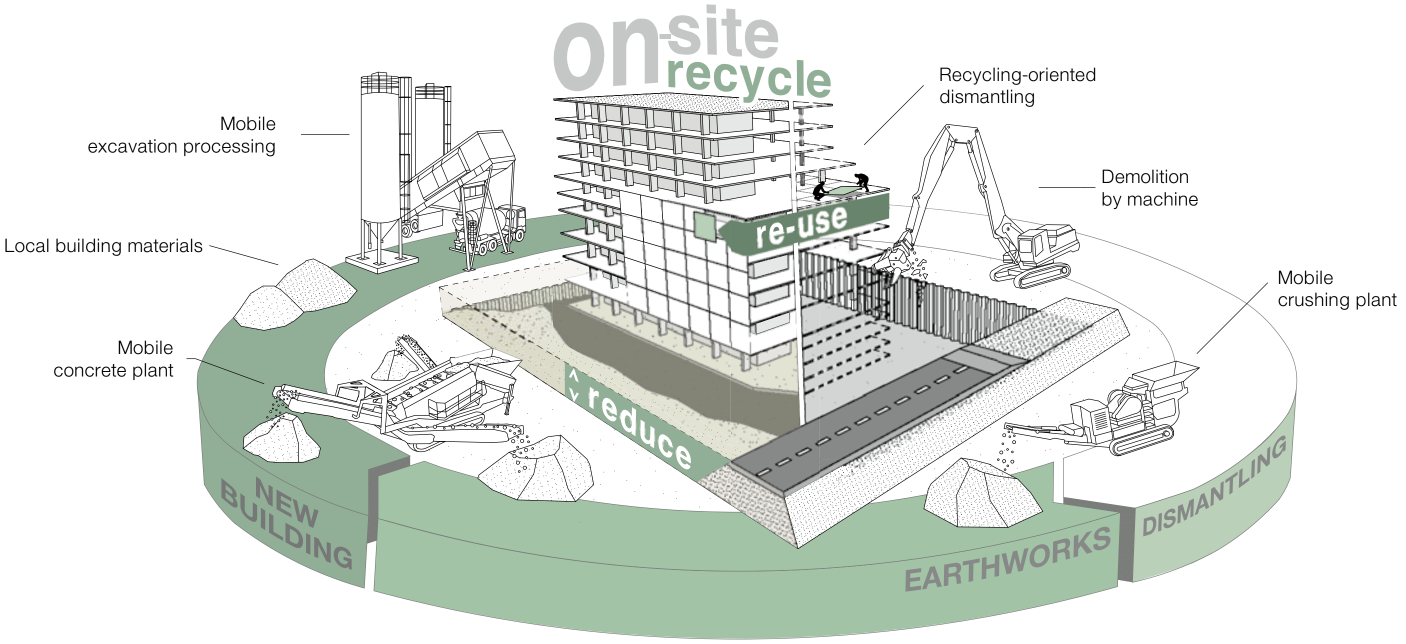
A 6.1

The “Vienna Model”

The “Vienna Model” is the systematic approach that the Austrian capital uses to secure cost-effective construction and affordable housing in Vienna, an “environmental model city”. A thoughtful use of resources is part of this quality assurance, which, despite the doubling of annual production to 10,000 residential units in the past 20 years, guarantees a high degree of sustainability. Challenges such as climate change (increasingly frequent torrential rain events and long dry periods) and population growth resulting from mass migration must be met with sustainable strategies. An urban mining concept that aims to maximise recycling rates in building projects is a good way of increasing the environmental efficiency of construction work (see “Circularity in Architecture – Urban Mining Design”, p. 10ff.). Balancing earthworks over a number of building sites and the efficient use of resources in individual construction work steps are both anchored in a large-scale urban development project master plan. The large-scale construction sites of Vienna’s new central railway station and the former Aspern airfield site, where the “Seestadt Wien” with apartments for 20,000 residents and thousands of workplaces has been built since the master plan was adopted in 2007, are current examples of this kind of successful resource planning in urban development and its implementation on building sites. Urban mining has now become firmly established in construction at the large-scale project development level. This reflects the local government’s policy decision to improve the building industry’s business and management strategies through development designed to benefit the wider public over a number of building sites. This type of recycling strategy is consistent with the EU Waste Framework Directive demand (see “The Legal Background”, p. 16ff.) that waste be avoided. In Vienna it emerged out of a decades-long dialogue between the public sector and the building industry that had its origins in the joint development of their Guidelines for Sustainable Construction Site Management (Richtlinien für umweltfreundliche Baustellenabwicklung or RUMBA).

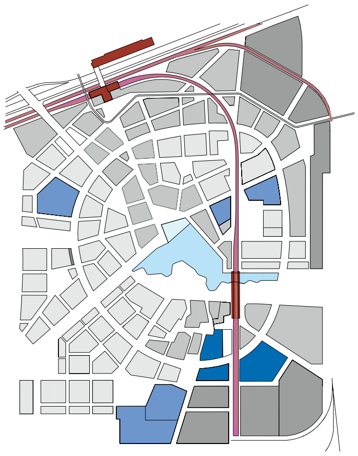
Sustainable mass flow management aims to obtain most of the building materials required from the construction activity itself. The preconditions for this include the specifications of the urban development master plan, which forms a basis for zoning. Among the key factors for successful on-site recycling are the detailed planning of materials flows for balancing earthworks within the building area and logistical implementation of local recovery and recycling during the construction phase.

BIM (Building Information Modelling) is used to analyse materials in the recovery-oriented dismantling of buildings. A preceding survey of any pollutants and impurities results in a dismantling plan that provides a quantity structure. The materials flows expected from the dismantling are classified according to their recoverability and recycling and processing on the building site is included in the demolition contract. This matrix quantifies applications for crushed materials by sieve fraction, such as technical filling material, roadbed, drainage material and aggregates as substrata for plants. The structure of angular crushed rubble,



A 6.2

A 6.3



A 6.4

A 6.3 On-site concrete plant in Aspern with gravel processing
A 6.4 Aspern Süd master plan, Vienna (AT) 2006, Master plan: Tovatt Architects & Planners with N+ Objektmanagement
A 6.5 On-site concrete concept: All types of concrete and all the in-situ concrete required was produced entirely on site. Using a closed system that is not dependent on groundwater, the plant operator processes aggregate fractions using wet processing to make high-quality types of concrete (higher than XC1).
A 6.6 Aspern Süd site at the start of building with the construction logistics centre 2014

for example, means that it is usually ideal for civil engineering applications.

Mobile machines can process gravel and sand from pit excavations into concrete on-site. The materials are screened, crushed and classified as aggregates for concrete on-site (Fig. A 6.3). Based on a BIM evaluation of soil analyses to assess the soil's geotechnical properties and compliance with waste management legislation and taking the volume of extracted earth into account, it is possible to forecast the potential extent of local recovery and recycling (Fig. A 6.5). Gravelly sand that is further processed after simple dry screening can be used in 50 % of the concretes commonly used in building construction. Wet processing that is not dependent on groundwater can also be used for this purpose. All qualities of concrete can be made on-site out of these washed aggregates. This process is ecologically as well as economically effective. On-site recycling, direct recycling in situ, makes for shorter construction times, saves transport and disassembly costs, and reduces a structure's environmental impact.

The principle of "recovery and recycling instead of transport" has an enormous environmental impact. Two-thirds of inner-city freight transport is to and from building sites [2] and heavy vehicle transport causes a large proportion of local fine dust particle emissions. Intelligent recovery and recycling logistics on building sites reduces emissions such as airborne pollutants, noise, and fine dust while optimising cost benefits and giving rise to a cyclical process that covers dismantling, earthworks and the construction of the building's shell, offering the building industry new business models. The two forward-looking building projects described below are examples of successfully implemented urban mining.

Project example – Vienna's Aspern Seestadt

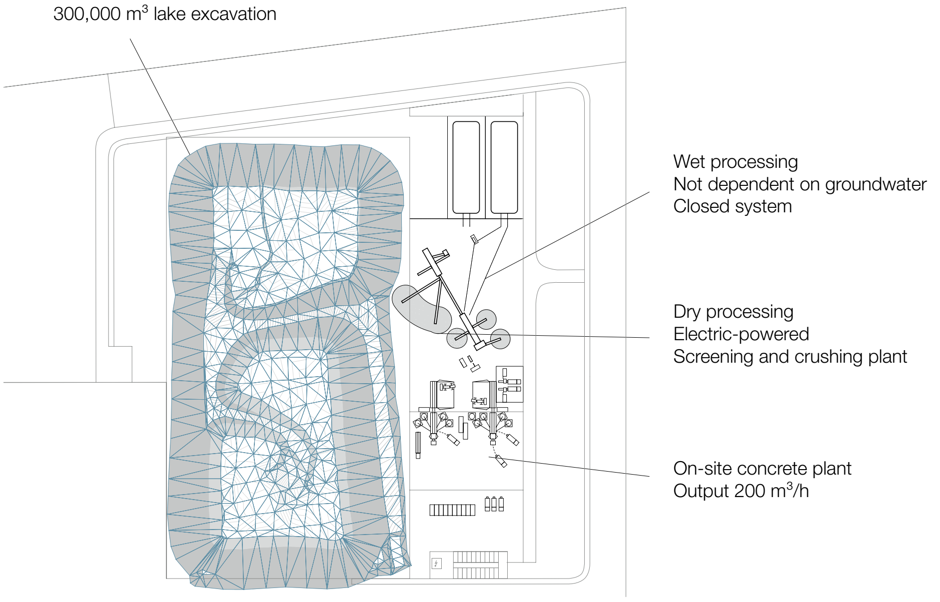
Aspern Seestadt is one of the world's largest urban development projects, covering 240 hectares (Fig. A 6.6). The project development company has supported urban mining since construction began, setting up a logistics subsidiary specially for this purpose. A case study shows how more than one million tonnes of material was locally processed and used in the construction of the first 3,000 apartments. Balancing earthworks – the raising of the ground elevation level for road building – enabled the volume of excavated earth to be halved and excavated earth material to be used in road building and as aggregate for concrete. All the grades of concrete and all the in-situ concrete required were produced exclusively using local gravel directly on the building site (Fig. A 6.5). The plant was designed to produce a peak output of 2,000 m^3 of concrete and in fact achieved this daily output several times. All the types of aggregate were processed using a closed wet processing system that was not dependent on groundwater. Only 5 % of the washing water adhering to the gravel was fed back into the water cycle. Despite the cost and effort involved in management and quality assurance, a bill of quantities calculating the extra costs and reduced costs revealed clear economic advantages that did, however, vary from building site to building site and resulted from the savings obtained from reduced transport mileage and better availability of raw materials.

Project example – "Biotope City"

Another case study examined the ambitious "Biotope City" residential project, a dense yet very green development of around 1,000 residential units on the site of a former production plant in Vienna, whose 50,000 m^2 area had been completely built over and sealed. Here, an urban mining approach was used to support the goal of creating a resilient habitat that would adapt to the consequences of climate change and allow for high levels of biodiversity in the city by providing a consistent maximum greening of facades and roofs and unsealed open spaces. The strategy centred on using plant and soil substrata for the long term and on the near-natural greening of buildings and open spaces that require very little care and maintenance. The use of partly locally-sourced secondary raw materials make it possible to retain more water [3]. The University of Natural Resources and Life Sciences, Vienna (Universität für Bodenkultur Wien) hosted accompanying research programmes and has issued scientific publications on this topic [4]. For this pilot project, the value creation as well as the recovery and recycling of structural components is achieved via a cooperative network of socio-economic enterprises, covering everything from recycling through to re-use and going well beyond merely managing materials flows in the area under construction itself.

Conclusion: legal aspects

Three legislative aspects must be emphasised in highlighting the “Vienna Model” as implementing European circular economy principles in construction. The first of these is the top priority of avoiding waste. The EU Waste Framework Directive does not classify as waste excavated soil materials that are reused where they are extracted. This exception absolves builders from compliance with a further series of legal obligations involving waste treatment – whether in disposing of it in landfill or recovering and re-using it elsewhere. From a European law perspective, using waste for the production and utilisation of recycled building materials is also necessary in terms of two other aspects. On the one hand there is the obligation of EU member states prescribed in the Waste Framework Directive to comply with a recycling rate of 70 % for non-hazardous construction and demolition waste by 2020. On the other hand, there is the EU Construction Products Regulation, which prescribes the use of secondary raw materials for every new building (see “The Legal Background”, p. 16ff.).



A 6.5

A 6.6

Notes:

[1] The United Nations Environment Programme (UNEP) does not have reliable data on output quantities of mineral building materials for all regions of the Earth, so the amount is deduced indirectly from data on cement production, which tripled in the period from 1994 to 2012. https://wedocs.unep.org/bitstream/handle/20.500.11822/8665/GEAS_Mar2014_Sand_Mining.pdf?sequence=3. Retrieved on 07.06.2019

[2] Guidelines for sustainable construction site management, final technical report, EU-LIFE research project, project number LIFE00 ENV/A/000239. Published by the MD-Stadtbaudirektion of the City of Vienna (Stadt Wien). Vienna, 2004, http://www.rumba-info.at/files/kurzbericht_rumba_englisch.pdf. Retrieved on 07.06.2019

[3] e.g. the production of roof substrata based on compost and brick chippings in recycling plants. https://www.optigreen.co.uk/products/substrates/. Retrieved on 07.06.2019

[4] https://forschung.boku.ac.at/fis/suchen.projekt_uebersicht?sprache_in=en&ansicht_in=&menue_id_in=300&id_in=11057
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Local architects: Berkebile Nelson Immenschuh McDowell Architects, Kansas City
Structural engineering: Guy Nordenson & Associates, New York

Window Factory in Hagendorn (CH)
Architects: Graber & Steiger, Lucerne
Project team: Urs Schmid (project management), Roland Stutz (project management), David Zimmermann
Structural engineering: Locher AG, Zurich

Community Centre in St. Gerold (AT)
Architects: Cukrowicz Nachbaur Architekten, Bregenz
Project team: Stefan Abbrederis (project management), Michael Abt, Christian Schmölz
Structural engineering: M+G Ingenieure, Feldkirch

Wood Innovation and Design Centre in Prince George (CA)
Architects: Michael Green Architecture, Vancouver
Project team: Mingyuk Chen, Carla Smith, Seng Tsoi, Kristalee Berger, Alfonso Bonilla, Jordan van Dijk, Guadalupe Font, Adrienne Gibbs, Jacqueline Green, Asher deGroot, Soo Han, Kristen Jamieson, Vuk Krcmar-Grkavac, Alexander Kobald, Sindhu Mahadevan, Maria Mora
Structural engineering: Equilibrium Consulting, Vancouver

Aktivhaus Residential Estate in Winnenden (DE)
Architects: Werner Sobek, Stuttgart
Project team: Stephanie Fiederer, Thorsten Klaus, Frank Peiser, Alen Masic
Structural engineering: Werner Sobek, Stuttgart

Holiday Home in Kumrovec (HR)
Architects: Proarh, Zagreb
Project team: Davor Mateković (project management), Oskar Rajko
Structural engineering: Branko Galić, Zagreb

Residence in Vorarlberg (AT)
Architects: Georg Bechter Architektur + Design, Langenegg
Project team: Anna Höss
Structural engineering: Eric Leitner, Schröcken

Office Building in St. Johann in Tyrol (AT)
Architects: architekturwerkstatt Bruno Moser, Breitenbach am Inn
Project team: Bruno Moser, Florian Schmid, Thomas Schiegl
Structural engineering: dibral, Alfred R. Brunnsteiner, Natters

European School in Frankfurt am Main (DE)
Architects: NKBAK, Frankfurt am Main
Project team: Simon Bielmeier, Larissa Heller
Structural engineering: Bollinger + Grohmann Ingenieure, Frankfurt am Main
merz kley partner, Dornbirn

Wadden Sea Centre in Ribe (DK)
Architects: Dorte Mandrup, Copenhagen
Project team: Kasper Pilemand (project management)
Structural engineering: Anders Christensen, Birkerød

The Rauch House in Schlins (AT)
Architects: Planungsgemeinschaft Roger Boltshauser, Zurich, with Martin Rauch, Schlins
Collaborators: Thomas Kamm (project management), Ariane Wilson, Andreas Skambas
Structural engineering: Josef Tomaselli, Bludesch

Residence in Deitlingen (CH)
Architects: spaceshop Architekten, Biel
Project team: Raphaël Oehler, Beno Aeschlimann, Stefan Hess, Reto Mosimann
Timber structural engineering: TS Holzbauplanung, Ersigen
Loam construction consulting: Ralph Künzler, Winterthur

Villa Welpeloo in Enschede (NL)
Architects: 2012 Architecten, Rotterdam
Project team: John Bosma, Frank Feder
Structural engineering: Nico Plukkel Bouwkundig, Haarlem

Upcycle House in Nyborg (DK)
Architects: Lendager Group, Copenhagen
Collaborators: Anders Lendager (project management), Rune Sjöstedt Sode, Christoffer Carlsen, Jenny Haraldsdottir, Anna Zobe
Structural engineering: MOE Rådgivende Ingeniører, Copenhagen

Folkwang Museum Building Extension in Essen (DE)
Architects: David Chipperfield Architects, Berlin
Project team: Ulrike Eberhardt (project management), Eberhard Veit (project management), Markus Bauer, Florian Dierschedl, Annette Flohrschütz, Gesche Gerber, Christian Helfrich, Barbara Koller, Nicolas Kulemeyer, Dalia Liksaite, Marcus Mathias, Peter von Matuschka, Sebastian von Oppen, Ilona Priwitzer, Mariska Rohde, Franziska Rusch, Antonia Schlegel, Marika Schmidt, Thomas Schöpf, Gunda Schulz, Manuel Seebass, Robert Westphal
Executing architects: PLAN FORWARD, Stuttgart
Structural engineering: Pühl und Becker, Essen

Cultural Institute, Formerly Hombroich Rocket Station near Neuss (DE)
Architects: Alvaro Siza, Porto, with Finsterwalder Architekten, Stephanskirchen
Project team: Burkhard Damm, José Diniz Santos, Matthias Heskamp, Heinz Kirschner, Steffi Zucker
Structural engineering: Horst Kappauf, Monheim am Rhein

History Museum in Ningbo (CN)
Architects: Amateur Architecture Studio, Hangzhou
Wang Shu, Lu Wenyu
Project team: Song Shuhua, Jiang Weihua, Chen Lichao
Structural engineering: Shentu Tuanbing, Hangzhou

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A 2.4	Anja Rosen, source: Federal Statistical Office, waste balance 2014 (waste generation and whereabouts waste classifications, waste generated by industry branch). Wiesbaden 2016
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A 2.6	Anja Rosen, source: Kreislaufwirtschaft Bau Initiative, published by Bundesverband Baustoffe – Steine und Erden e. V., report on the generation and whereabouts of mineral construction wastes in 2014. Berlin 2017
A 2.7	After Stoll, Michael: “Recycling von mineralischen Abfällen – Aktueller Stand und Ausblick aus Sicht der Wirtschaft”. In: Thomé-Kozmiensky, Karl J. (eds.): Mineralische Nebenprodukte und Abfälle. Nietwerder 2014
A 2.8	Anja Rosen, based on Institut für Bau und Umwelt, Hochschule Rapperswil, in collaboration with Holcim (Schweiz) AG, life cycle assessments of recycled aggregates for concrete. Zurich 2010
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A 2.14, 2.15	Anja Rosen, based on: Deilmann et al.: Materialströme im Hochbau, Forschung für die Praxis, Vol. 06, published by Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) in the Bundesamt für Bauwesen und Raumordnung (BBR) Bonn, 2017
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An Overview of Rating Systems

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A 3.4	Anja Rosen, based on Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) e. V. (eds.): DGNB System, Kriterienkatalog Gebäude Neubau, Version 2018, Kriterium TEC1.6 Rückbau- und Recyclingfreundlichkeit
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B 7.11	Petra Riegler-Floors, based on BKI – Baukosten 2016 Neubau part 3: Nutzungsdauern von Bauteilen zur Lebenszyklusanalyse as well as on BNB and information from Paul Kamrath Ingenieurrückbau GmbH
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