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RECYCLED CONCRETE AND LOW-CARBON CEMENT

KEY TAKE-AWAYS

For the past 20 years, Zurich has championed the use of **recycled concrete in buildings** to preserve nature and reduce local urban waste. By requiring a **minimum share of recycled aggregates** in concrete for **new buildings,** Zurich's **public procurement policy created a market for recycled concrete** in construction.

Zurich also pushed for the first Swiss **standards for recycled concrete,** introduced in 1994, and contributed to their revisions in 2010 and 2021.

As more suppliers moved into recycled concrete production, and users' confidence in the product grew, the market **expanded into the private sector.**

As a next step, the city of Zurich explored options to **reduce greenhouse gas emissions in construction.** Since 2013 Zurich has required the use of **low-carbon cement,** in addition to recycled concrete, for new public buildings. Zurich also initiated pilot projects for the **reuse of building parts** in both new builds and retrofits.

OVERVIEW

In 2002, the city of Zurich launched a **pilot project** to demonstrate the feasibility of using a **high level (80 percent) of recycled aggregates in concrete** and built a new school.

Based on the results of this successful partnership with a local recycled concrete producer, in 2005 the city introduced a **25 percent minimum requirement for recycled aggregates in concrete** as part of its **public procurement** policies for new buildings.

Subsequently Zurich sought to **reduce the energy and carbon footprint of recycled concrete.** In 2013 the city amended further its procurement policy to **require the use of low-carbon cement.**

Together with the **revision of national standards for recycled concrete** and **communication** efforts towards stakeholders, Zurich's public procurement policy succeeded in **creating a market for recycled concrete** that **spread to the private market,** making the use of recycled concrete in construction **commonplace** today.

Co-benefits of using recycled concrete:

- → **Land preservation,** as less construction and demolition waste is sent to landfills, and excavations for virgin material are avoided.
- → **Resource efficiency,** as it reduces the use of virgin basic materials like sand and gravel.
- → **Savings,** as the cost of sending construction and demolition waste to landfills is avoided.

AIMS & TARGETS

The city of Zurich's first objective was to **reduce the amount of construction and demolition waste** (CDW) and **safeguard** the local **landscape from gravel excavations.** Recycled materials from CDW can replace a share of concrete's main components – gravel, crushed rocks and sand (i.e. aggregates) – thereby reducing the amount of virgin materials needed and the amount of CDW sent to landfills.

Zurich started with **improving waste sorting** on demolition sites in the 1990s to facilitate a **higher-quality recycling** of waste materials. Recycled concrete was already used as a road filler, for lower-strength construction work. A higher quality of recycled concrete was necessary for the construction of buildings.

The city set out to **develop a local market** for recycled concrete for the construction of buildings. The city **trialed recycled concrete** before going forward with a **full-scale public building demonstration project** in the early 2000s. Afterward the city **created a stable demand** for recycled concrete through its **public procurement policy.**

By setting **minimum requirements for recycled concrete** use in new public buildings, the city has strived to use as much recycled concrete as possible. Zurich also chose to promote the recycling of mixed demolition waste in recycled concrete. With more construction companies vying for government contracts, a **market developed** over time, eventually **extending into the private buildings sector.**

Beyond waste reduction and nature preservation, the city looked into ways to **reduce the energy and carbon footprint of buildings, targeting concrete,** in the late 2000s. Zurich decided to use **low-carbon cement** for new buildings and in 2013 introduced it as a **requirement** in public procurement.

In order to further reduce the carbon footprint of its buildings stock, the city of Zurich has also started pilot projects on the **reuse of buildings parts** to gather insights on potentials and constraints moving forward.

POLICY INSTRUMENTS

The city of Zurich's environmental strategy

- → Concerns over nature conservation led to a focus on **urban waste from construction** in the 1990s.
- → With the adoption of the '2,000-Watt Society' initiative in 2008, Zurich developed targets and schemes to **reduce the city's energy consumption and greenhouse gas (GHG) emissions** over time. The city developed its first '7-Milestone' *(7 Meilenschritte[1])* plan for environmentally friendly and energy-efficient construction in 2010. The city aimed for almost all new constructions, such as housing estates, school buildings and retirement homes, to be low-energy housing ('Minergie standard'). Later the plan covered the entire **lifecycle of buildings,** and concrete was identified as a major source of **embodied carbon** in new builds.[2]
- → In 2022, Zurich increased its ambition and now aims to become **climate neutral by 2040.** For the city's administration, the net zero[3] target is set for 2035.[4] As for indirect emissions (scope 3[5]) the city aims for a reduction of 30% by 2035 compared to 1990 levels.[6]

Public procurement and minimum requirements

- → Zurich, **the largest city** in Switzerland, had a **public procurement budget** of 1.8 billion euros in 2019.

1 https://www.stadt-zuerich.ch/hbd/de/index/hochbau/beratung/nachhaltiges-bauen/7-meilenschritte.html

2 For more information on embodied carbon in buildings, see https://www.agora-energiewende.de/en/success-stories/re2020-in-france/

3 'Net zero means cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance.' See https://www.un.org/en/climatechange/net-zero-coalition

4 https://www.stadt-zuerich.ch/portal/en/index/portraet_der_stadt_zuerich/environmental-strategy.html

5 Measurement standards cover three types of emissions: direct emissions from an organisation's activities (called scope 1), indirect emissions from energy consumption (scope 2), and other indirect emissions along the organisation's value chain (scope 3). For more information, see https://ec.europa.eu/environment/emas/index_en.htm ; https://ghgprotocol.org/scope-3-technical-calculation-guidance ; https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities

6 https://www.stadt-zuerich.ch/gud/de/index/departement/strategie_politik/umweltstrategie/klimapolitik/klimaschutz/net-to-null-treibhausgase.html

The city spent 370 million euros on new public buildings[7], with **15 to 25 percent,** or 55 to 90 million euros, going toward the **structural work of the building** (the concrete structure and shell).[8] The size of the city's yearly budget **creates a demand** that **influences the local construction market.**

- In the 1990s, Zurich began to require **improved waste sorting on demolition sites.**
- The city introduced new requirements in 2005: a **minimum of 25 percent of recycled aggregates in concrete,** in line with SN EN 206:2013 and SIA 2030 standards. In addition, the city required RC-C quality as a minimum, and where technically possible, RC-M quality, aiming for **a 25 to 50 percent minimum range** depending on the recovered demolition waste in concrete.[9]
- In 2013, Zurich required the use **of low-carbon cement to reduce embodied carbon emissions** from concrete, in line with the existing CEM III/B cement standard,[10] the best available solution available on the market at the time.

Demonstration projects and capacity building

- In 2002, the city partnered with a local construction company and a local concrete producer to build its **first public building with recycled concrete. New techniques to produce recycled concrete were developed** in the process. The building – a new school – contains concrete with 80 percent recycled aggregates, and cost around 78 million euros.
- Concrete's smallest component, cement, is responsible for more than 70 percent of its GHG emissions due to the energy intensity of clinker[11] production.[12] A way to reduce emissions from cement is by replacing a portion of clinker with a lower-emission ingredient. The city of Zurich carried out a **study to compare different cement production methods and their GHG emissions.** The study found that a cement type called CEM III/B[13] reduced carbon emissions by 25–30 percent compared with conventional concrete.[14]
- In response to quality concerns by architects and other stakeholders in the buildings industry, in 2016 the city created a **mock-up wall** displaying a **direct comparison of aggregate and cement types in concrete.** The mock-up wall showed there were little aesthetic differences and limited end-characteristics differences between cement and concrete types. The use of CEMIII/B cement gives the concrete a lighter color that is appreciated by architects on aesthetic grounds.[15]
- The city of Zurich supports **architectural competitions** to foster not only the **use of recycled materials** but also the **reuse of building parts.** The city looks at buildings that are slated for demolition, analyzes different techniques to understand which building parts can be reused, and offers a catalogue so architects can build a new building out of reused parts.[16]

Standards

- In the 1990s, the city of Zurich started a dialogue on its policy goals, tests and pilot schemes with the **national standardisation body for buildings,** the Swiss Society of Engineers and Architects (SIA), in light of the existing national standards for cement and concrete.
- **Standards for recycled concrete** were first published in 1994, and then revised in 2010 and 2021. In the 2000s standards moved from being based solely on **composition** to include **performance** considerations as well.[17]

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7 In 2021 the city of Zurich spent 504 million euros on refurbished and new buildings (source: Armin Grieder, city of Zurich).
8 European Commission, 2019.
9 RC stands for recycled concrete, C for concrete demolition waste and M for mixed demolition waste. For details see city of Zurich, 2017 and European Commission, 2019.
10 European Commission, 2019.
11 Cement is a binding material typically made from heating limestone with clay or shale, which is then grinded into a fine powder called clinker.
12 This process results in around 680 kg CO_2 emissions per tonne of cement, or 250 kg CO_2 emissions per tonne of concrete.
13 CEM III/B replaces 66 – 80 percent of clinker with slag-sand, a by-product of traditional iron production, using the blast furnace route.
14 European Commission, 2019.
15 City of Zurich, 2017; European Commission, 2019.
16 Interview with Philipp Noger, city of Zurich, June 11, 2021.
17 Interview with Armin Grieder, city of Zurich, September 29, 2021.

ACHIEVEMENTS & LESSONS LEARNED

Local public and private markets for recycled concrete in buildings

- Today, **recycled concrete** is used in **all of Zurich's public buildings whenever technically feasible.** Around 90 percent of the concrete used for public buildings is recycled concrete, consisting of up to 50 percent of recycled aggregates. A building can now be made with up to 98 percent of recycled concrete.[18]
- **Supply followed demand.** As Zurich required recycled concrete for its new public buildings, more suppliers invested in production capacities in order to compete for the municipality's bids. By the end of the 2000s, there were eight to ten **local recycled concrete suppliers.**[19]
- **In recent private buildings, up to 50 percent of the concrete is made from recycled aggregates.**[20]
- Zurich's success shows a high level of recycled concrete can be applied in new buildings for the **same cost and use** as conventional concrete, without having to choose between safety, quality, aesthetics and other important factors.

Savings of virgin materials and landfill space

- By 2019, approximately **17,000 cubic metres of virgin materials,** along with **landfill space, were spared** due to the use of recycled concrete for buildings' construction.[21]

Awareness raising and skills

More **students** in universities in Switzerland show interest in learning about recycled materials and the reuse of building parts for new buildings.[22]

18 European Commission, 2019.
19 European Commission, 2019.
20 European Commission, 2019.
21 European Commission, 2019.
22 Interview with Philipp Noger, city of Zurich, June 11, 2021.

Developing a strategy for recycled concrete and low-carbon cement

- **Public awareness** on the importance of land preservation and climate protection was key to helping Zurich shift to recycled concrete.
- From the outset, the city involved local producers and technical support. The **collaboration** has proven useful in understanding and developing the recycled concrete **production processes** and in showing the **feasibility** of using recycled concrete in buildings.
- The city also engaged in the necessary **dialogues** at the national level regarding concrete and cement **standards,** so that they would eventually reflect the know-how developed in Zurich regarding recycled concrete.
- Using recycled material only makes sense when it is **locally available.** It is useful in **urban areas** with high density and a **constant stream of construction and demolition waste.**[23] For Zurich it implies recycling concrete within a 25-kilometre radius of the construction site, which covers the greater Zurich area.
- A **high-quality sorting** of **construction materials** at demolition sites is required for recycling concrete (this is already mandatory in some EU countries).

Implications for standards

- **Harmonised standards for cement** at the **EU level** are based mainly on **composition, rather than performance.** To allow for innovation, there is a fast-track route of roughly 18 months to obtain the **CE mark,**[24] allowing market entry in all member states. However, as the need for low-carbon materials grows in response to Europe's climate neutrality goals, **existing standards** will have to be **revised**[25] to allow for **innovative performance solutions.**

23 Global Recycling, 2019.
24 Given all required tests are successfully done, which takes a minimum of 2 to 3 years and is costly. CE stands for "conformité européenne" and indicates conformity with European standards.
25 A performance-based approach for cement is under consideration at the European Commission. Besides, a dedicated technical committee was recently created to develop related testing methods at the International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM).

- **Non-harmonised standards** for **concrete** apply at the **Member State level** and may restrict market entry to innovative products without the CE mark. To facilitate the use of new low-carbon products, the European Committee for Standardization (CEN) has published two non-harmonised standards on low-carbon cements (EN197-5 and EN197-6) that are expected to be included into the national non-harmonised standards of its member countries (cf. CEN/TC51).

Current technology developments for buildings

Numerous innovative technologies are being developed in the buildings and concrete sectors across Europe. The vast majority are aimed at **using less concrete,** producing **concrete with less cement,** or **reducing carbon emissions in cement** production. Another option, **storing carbon in concrete,** has recently become available. Another innovative solution is the **recycling of concrete inclusive of most of the cement.** Lastly, the **reuse of buildings parts** is also gaining grounds.[26]

- **Design:** the quantity of material used can be minimised through design while serving the same function. It can be done at the component level, for a set of components or at building level.
- **Alternative binders:** a **second generation of cement** is available using low-carbon binders, made for instance with blast-furnace slag, a by-product of coal-based steel production, or fly and bottom ashes, a by-product of coal-fired power plants, or calcined clays and others.[27] These processes can **save** around **10-30 percent,** and for some solutions around **40-60 percent** or more of **GHG emissions** compared with conventional cement. However, blast-furnace slag availability is limited and will become increasingly so as coal-based steel production will be phased out. The same is true for fly and bottom ashes, with the phase-out of coal for electricity production. Other waste streams could be used in the future, such as ashes from household waste incineration, or red mud from aluminium production, next to natural resources such as volcanic ashes that are abundant in some places (e.g. in Europe: Italy, Greece and Slovenia).
  A third-generation cement is being developed using various materials (such as plastic waste) for a diversity of applications. A few viable solutions are currently market ready. Most are not expected for another 10 to 15 years.
- **Carbon storage via recarbonation:** Concrete aggregate obtained from the demolition of buildings is mixed with CO_2 (e.g. carbon captured from flue gases or even the atmosphere). Through a process known as mineralization, the carbon dioxide is permanently bound in the concrete aggregate. The treated aggregate is then added to fresh concrete as a substitute for gravel.[28]
- **Recycling:** A large part of cement does not react when concrete is made. Recycling the sand, gravel and cement back into their original ingredients allows to produce **recycled *cement*[29] and concrete.** This method requires a small amount of virgin cement on top of the recycled cement to produce fresh cement, resulting in limited process emissions. It is currently at the demonstration stage.[30]
- **Reuse:** the reuse of concrete parts from old buildings is being explored for new build, either on site or in a new site. In addition, new building design is exploring construction elements for disassembly and reassembly, during and after the building's lifetime.

Besides, in order to achieve climate neutrality by 2050, the cement sector plans to resort to carbon capture, utilisation and underground storage (CCS/CCUS) to address residual emissions.

26 Interviews with Hubert Rahier, VUB, October 18, 2021, and Jean Michel Torrenti, Gustave Eiffel University, October 19, 2021.

27 Known as alkali-activated materials or geopolymers.

28 This technology is available on the market. See for instance the Swiss start-up *neustark*. https://www.neustark.com/about

29 Up to 95 percent of the cement can be recovered, depending on the original quality of the concrete. Interview with Koos Schenk, SmartCrusher, October 13, 2021.

30 See https://upconcrete.vito.be/en/about-project

GHG EMISSIONS REDUCTIONS & COSTS

In Zurich, the use of a **low-carbon cement** such as CEMIII/B **reduces process-based carbon emissions by around 25 to 30 percent** compared with conventional concrete.

Over 2016 to 2021 the city consumed around 31,900 cubic metres of concrete per year, of which about 19,100 cubic metres were made with CEM III/B, or around two thirds on average. Since 2020, the share of concrete made with CEM III/B has reached approximately 80 percent. As a result, about 7 430 tonnes of carbon dioxide were saved over the six-year period (indirect emissions, scope 3).[31]

31 Interview with Armin Grieder, city of Zurich, September 29, 2021.

Recycled concrete is around the **same price or slightly cheaper** than virgin concrete (around 178 euros per cubic metre in 2019).[32] The small cost differential saved by avoiding virgin materials is more or less compensated by the higher energy consumption required for recycled concrete production.[33]

32 European Commission, 2019.
33 Interview with Philipp Noger, city of Zurich, June 11, 2021.

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