Positive picture of the future thanks to new concrete recycling methods

Ambitions to reduce primary raw materials only promising with innovations

There are plenty of opportunities in the circular economy for concrete. Although the profit is greatest from the reuse of buildings or constructions, the best-known example is still the reuse of concrete rubble as granulate in new concrete. But the latter does not always result in a reduction of CO emissions. However, new recycling methods can significantly increase the quality and replacement percentage of the granulate and create more opportunities with regard to CO reduction.

The government-wide program The Netherlands Circular in 2050 [1] sets out how we can transform the economy into a sustainable, fully circular economy in 2050. The programme, launched in 2016, describes what is needed to be more efficient and smarter with raw materials, products and services. to go. A Concrete Agreement [2] was drawn up in 2018, a national chain agreement for sustainable growth of the concrete sector, which was signed by the government and the business community (clients, contracting companies, engineering firms, recycling companies, suppliers of raw materials, concrete suppliers). In this agreement, agreements have been made about which chain partner will realize which goals and ambitions. In order to formulate a concrete approach, implementation teams have been set up within the Concrete Agreement on a number of subjects: CO2 reduction, circular design, reuse of concrete residual flows, impact on natural capital, MKI, knowledge and innovation, and education and knowledge sharing. These teams have now finished their work and have been disbanded.

Reuse concrete

Concrete rubble can be reused excellently in new concrete if certain conditions are met. Important there

Another point is that making the concrete chain more sustainable should in any case not be at the expense of the quality of the concrete. After all, a shorter life comes durability the concrete is not good either. The goal is therefore the highest possible reuse.

Therefore, just like primary raw materials, quality requirements are also set for recycled raw materials. The extent to which materials can be reused is related to the quality and purity of the source

material. For example, for all flows of recycling granulate, in accordance with assessment guideline BRL 2506, a maximum of 1% m/m. non-stony material (such as wood and/or plastic) may be present. Despite this apparently low percentage, it is experienced as too much and/or considered a risk for practice in some applications (eg floating components). However, there are also producers who can offer a lower percentage

to realize and thus without a doubt comparable to 'contaminants' (including primeval wood) that can also occur in natural primary material.

By the 'Reuse' implementation team concrete residual flows' of the Concrete Agreement is described in the 'Roadmap Reuse Concrete Residual Streams' [3] how to deal with the reuse of

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1 Recycling of released concrete (rubble) for use in new concrete, photo: Remko Kerkhoven / Betonhuis

Machine Translated by Google

Thanks to the new recycling techniques, new routes have become available to investigate how 'old' binder can be given a second life as a (new) binder

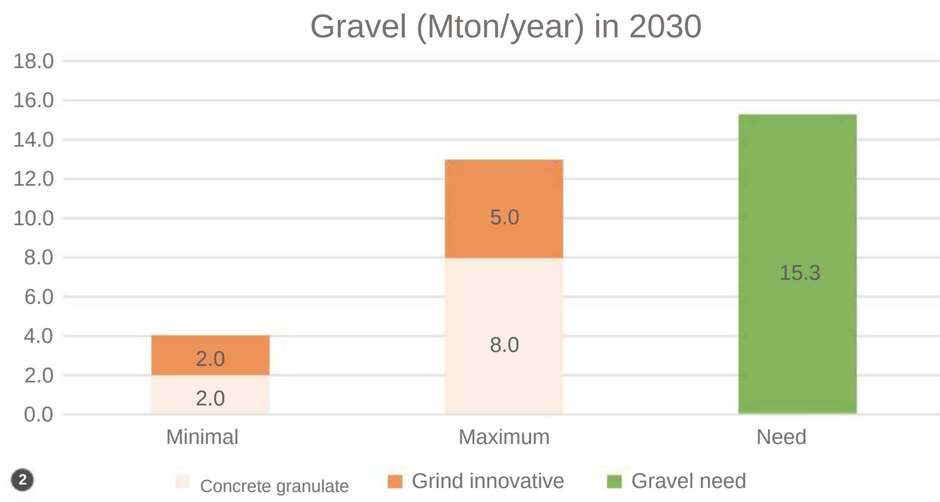

Table 1 Available amount of concrete rubble 2018-2030 [3]

	2018	2020	2025	2030
rubble released in NL (total) [Mton] 19		20	22	25
concrete rubble [Mton]	11.4	12	13.2	15

Table 2 Ambition percentage of the available fraction of the supply of concrete residual flows in which year is used in new concrete [2]

percentage of recycled supply	2020	2025	2030
gravel	50%	75%	100%)
sand	10%	50%	100%
binder/filler	1%	25%	100%

1) 100% corresponds to the replacement of approximately 15 – 20% primary raw materials

raw materials. For example, it is stated that in 2030 suppliers will supply a quality of concrete granulate that makes 100% reuse in new concrete possible, based on the growth path as stated in table 2 (see also box 'Concrete reservoirs in the Concrete Agreement'). In the same 'Roadmap Reuse Concrete Residual Streams' it is also explicitly stated that more attention must be given to the use of the fine fraction of concrete granulate, otherwise the reuse objectives cannot be achieved.

This article takes a closer look at the theme of reuse, and in particular the (high-quality) reuse of released concrete (rubble) for use in new concrete.

Modern recycling methods

The reuse of concrete is subject to certain limits. This is partly because application can influence mechanical and physical properties as well as the intended lifespan. The limits depend on the quality of the grain

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2 Comparison of supply and demand of coarse aggregate [3]

3 Traditional crushing of concrete produces two partial flows; to be called coarse concrete granulate (a) and (b) the fine concrete granulate fraction

CONCRETE STREAM IN IT CONCRETE AGREEMENT

The following ambitions have been formulated in the Concrete Agreement regarding the reuse of concrete residual flows:

- 100% of all concrete residual straw in 2030, the quality level will be that it can be used in new concrete, with transparency about the origin and composition of the residual flows, and connection to recognized quality marks and trans transparent measurement methods.
- 100% of all concrete residual straw it will be applied in 2030 in such a way that it can be used permanently in new concrete, in other words that no pollution or the like occurs through application, which hinders future reuse. stands.
- 100% take-back by the concrete chain of all the released concrete residual flows per 2030.

leave. For example, the determining factor is how much cement stone that adheres to the grains.

This cement stone ensures that the granulate is more porous than primary aggregate. In addition, it leads to a lower density. New concrete recycling methods (separation techniques) are currently available, which focus on the cleanest possible recovery of the original basic raw materials for concrete: sand, gravel and binding agent, with the aim of being able to use these materials, whether or not upcycled, as high-quality as possible. in the construction industry (more on these methods below).

On the one hand, these methods have the potential to separate materials in such a way that (complete) high-quality reuse (larger replacement percentages) in concrete (mixtures) is possible, while preserving quality.
On the other hand, new routes have also become available to investigate how 'old' binding agent can be given a second life, as a (new) binding agent (whether or not partially reprocessed) in new concrete mixtures (see also *Betoniek Vakblad).*
2020/3 'Recovery of cement from concrete' [4]).
For example, an ongoing PhD research is underway at the Faculty of Civil Engineering (department 3MD, M&E section, Sustainability research group), which focuses in particular on this very fine recovered fraction with the aim of restoring a suitable to make a binding agent. But also others research questions that have not been asked before become relevant in the context of determining the quality (binder used/ fillers/additives) in advance in the construction, in order to arrive at an efficient value determination of the recycled material (see *Cement* 2021/8 'Selective demolition of concrete structures' [5]).

For example, wind shifting techniques can be used to separate hydrated cement from unhydrated cement. Precisely the reuse of cement/binder can lead to a large reduction of COÿ, because this can limit the use of primary cement. Implementation routes to apply the (old) recovered binding agent (as high-quality) as possible are:

1 As an inert filler (type I addition) directly in the new concrete;
2 As a reactive filler (type II addition) directly in the concrete, where it can be used as a replacement for primary cement;
3 As a raw material for clinker production, requiring less primary limestone, resulting in lower initial CO_2 reduction;
4 As a raw material for composite cements (eg as a replacement for fly ash/trass etc.);

5 In combination with (alkaline) activator as a type of geopolymer.

New regulations

The innovative separation technologies have opened up a promising route to form a part in the (high-quality) closing of cycles in the concrete sector.
However, the lack of regulations for the (general) application of these modern separating materials is currently (still) an obstacle. The theme is on the agenda in various forums, such as in the implementation teams 'Knowledge and innovation' and 'Reuse concrete residual flows'.

In November 2021 there will be a new CROW CUR Recommendation published for the use of fine and coarse fraction recycling granulates obtained from (mainly) modern separation technologies (CROW-CUR Recommendation 127 Concrete with concrete granulate as fine and/or coarse aggregate [6], see article 'Higher percentages of reuse thanks to innovative recycling methods' elsewhere in this issue). The replacement percentage allowed therein is directly linked to the water absorption and thus to the quality of the fine and coarse concrete granulate. This is a new approach compared to the rules in CUR Recommendations 106 [7] and 112 [8] (Table 3).

At the moment there is still no concrete future development path for the reuse of the recovered binder (for example at the level of a recommendation), although there are European developments (CEN-TC51) where work is being done on the possibility of adding 20% cement stone recycle as a raw material (main constituent) →

Table 3 Maximum reuse percentage; considered relatively when applying existing CUR Recommendations [7,8] and the recently published CROW-CUR Recommendation 127:2021 [6] for modern recycled aggregates, expressed per m³ of concrete (only aggregate fine (sand) and coarse (gravel))

	reduction of primary materials		ambition 2030 (50% circular)	ambition 2050 (100% circular)
CUR 106 options fine recycled granulate	max. 50% fine	max. 50% fine + max. 20% coarse	not achievable	not achievable
reuse rate (per m³)	**approx. 17%**	**approx. 26%**		
CUR 112 options coarse concrete granulate	ÿ30% coarse	max.100% coarse	not achievable	
reuse percentage (per m³)	**approx. 13%**	**approx. 43%**		
CROW-CUR 127 Concrete with concrete granulate as fine and/or coarse aggregate	max. 60% fine + max. 100% coarse		feasible	
reuse rate (per m³)	**approx. 64%**			
future necessary developments				
development potential reuse and/or activation (reactive) filler	contribution to existing possible reuse percentage (per m³) approx. 15%		feasible	promising
reuse rate (per m³)	**approx. 79% to 100%**			
further development of fine recycled granulate obtained from modern separation technologies (replacement from max. 60% to 100%)	contribution to existing possible reuse percentage (per m³) approx. 15%		feasible	promising
reuse rate (per m³)	**approx. 79% to 100%**			

APPLICATION CONCRETE AND GRANULES

It is expected that by 2030 the total consumption of concrete per year will increase to approximately 15 million m³ of concrete. This requires approximately 27.8 million tons of aggregates (75 vol%), of which 12.5 million tons of sand (45%) and 15.3 million tons of gravel (55%). In addition, the production of concrete requires an estimated 4.8 million tons of cement [3].
In the most favorable case, we can assume that in 2030 approximately 15 million tons of concrete rubble will be available for use in new concrete (table 1). The mass distribution over the obtained coarse (4-32 mm) and the fine (0-4 mm) fraction of granulate is approximately equal (50/50).
At present, the reuse of processed (clean) concrete rubble as aggregate for concrete, even in the progressive Netherlands, is still limited. This is despite the fact that it has been the subject of study since the 1980s. Recycled concrete is largely (fine and coarse fraction together), mixed with <50% foreign material (stony such as sand-lime bricks, masonry and ceramics), used as foundation material for roads.

If concrete rubble is reused in concrete, this mainly concerns the coarse fraction (consisting of at least 90% concrete), for partial replacement of primary aggregate (particularly gravel). The fine fraction (also called crusher sand) cannot be used fully in concrete because the grain structure and composition often do not meet the requirements set in the aggregate standards. In concrete terms, the latter means that when the crushed fine and coarse fraction are separated, a surplus of fine recycled granulate (crusher sand) remains for which no useful application (not even for foundation material) can be found.

All this leads to a gap between the supply of secondary additives and the need (fig. 2), but also that a non-reusable part remains in the case of traditional recycling, making the ultimate intended circularity unattainable. is.

add to cement production. Of course, this development must be placed in perspective with other sustainability options (action perspectives) as stated in the Concrete Agreement, but it clearly shows that the field is currently under development, with a variety of sustainability options with associated new, as well as scientific as practical issues.

Recycling Methods

As indicated earlier, innovative mechanical recycling methods are currently being developed and/or are making the step towards further implementation in the market. The four main techniques are:

- Smart Liberator
- C2CA
- Circular Mineral
- mangeler

The first three methods already have installations that can produce on a practical scale. The Mangeler technique is in an upscaling phase, but it is expected that it will soon make the step to practical scale

to make. These four techniques are described below explained in more detail.

Smart Liberator The in the Netherlands meanwhile most developed technology is the Smart Libera

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It is precisely the reuse of cement that can lead to a large reduction of CO2, because this can limit the use of primary cement

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tor, at the Dutch company Smart Circular Products/Urban Mine (*Betoniek Vakblad* 2020/1 'An overview of innovative recycling methods' [9]). With this separation technique, from which five product flows arise, the adhered cement stone can be removed from the original sand and gravel by shear forces. The powdered cement stone is released as a separate production flow and can, for example, be used directly in concrete as a filler.

The high-quality partial flows are available under the product names:
- Freegravel – Gravel fraction (> 4 mm)
- Freesand – Sand fraction (0.25 mm/4 mm)
- Freefiller C – Fine fraction (0.08/0.25 mm), suitable as a filler
- Freement – Superfine reactive fraction (0.04/0.08 mm), suitable as cement/bond resourse
- Freefiller F – Ultrafine fraction (0/0.04 mm), suitable as binder/activator

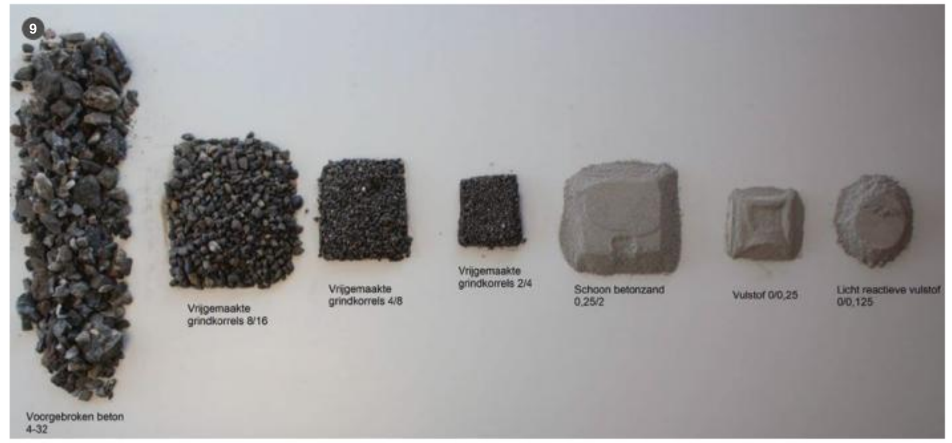
C2CA The C2CA method (Concrete to Cement & Aggregates) arose from a spin-off between a joint venture between GBN Groep (part of Strukton) and TU Delft. Using the ADR system (Advanced Dry Recovery), the collected concrete rubble is dry separated and processed directly from the crusher. On the basis of specific weight and dimensions, the concrete rubble is carefully and automatically separated during the process into at least three product flows with the following name:

- Circugrind – Coarse fraction (> 4 mm)
- Circu sand – Fine fraction (< 4 mm)
- Circument – Ultrafine fraction (< 0.2 mm), suitable as cement/binder

Circular Minerals Circular Minerals (CM) is an initiative of six Dutch demolition and recycling companies. In the so-called CM crusher, the concrete granulate is processed into sand, gravel and cement stone powder. →

4 Smart Liberator, Photo: New Horizon
5 Result of the crushing/grinding and separation process Smart Liberator, photo: Urban Mine BV, 2021

Only striving for circularity without taking sustainability into account in a broader sense can contradict the aim of reducing the ultimate environmental impact



The sand and gravel have an 80% clean surface. It is estimated that this will allow higher replacement percentages than on the basis of traditional materials, but lower than the two methods mentioned above. The cement stone powder can also be used here as a filler.

Mangeler A fourth method, which is expected to become operational on a practical scale in the short term, is the Mangeler method. This was developed by the Twee "R" Recycling Group. In addition to gravel and sand, this method also makes it possible to extract a binding agent from broken concrete rubble. The process uses, among other things, a CEM shifter (cyclone principle) developed for this purpose, which makes it possible to extract the very valuable to separate fine particles from the sand and gravel.

This last step in this method ensures that at least three partial straws are one arises.

Enabling responsible circular concrete

In order to assess the applicability of the recycled aggregate and binding agent in a new concrete construction or concrete product, it is necessary to record material properties and influences unambiguously and verifiably before application, as we are used to when using primary raw materials. This idea is in line with the objectives of the Concrete Agreement, which state that *'recycled materials or products are must meet the same quality requirements as primary materials and products'.* In fact can this be translated to that any concrete construction that is demolished and reused forms a new extraction site (Urban Mine), for which the properties of the materials to be extracted must be determined, in accordance with primary materials (see *Betoniek Vakblad* 2020/2, 'Responsible circular concrete' [10]). A harvest protocol, or a method for determining properties and quality, could be of great importance in this regard, in particular to determine the available quality in advance (see *Cement* 2021/8 'Selective demolition of concrete structures' [5]).

In *Betoniek Vakblad* 2020/3 'Recycling granulate: a reliable raw material' [11] it is stated, among other things, that the quality The quality and requirements of recycling granules for use in concrete are adequately guaranteed in the assessment guideline BRL 2506-1 Recycling granulates. In this BRL, however, an inspection regime is applied per batch of at least 500 tons of concrete rubble, without taking into account the unambiguous determination of the basic raw materials or reuse value of the rubble.

The advantage of this is that it is practical and meets the need that matched the philosophy as developed in the past for the recycling of construction and demolition waste. A major drawback, however, is that this batch of concrete rubble can consist of different (partial) flows, so with different qualities, contaminations and/or built up from different raw materials (think

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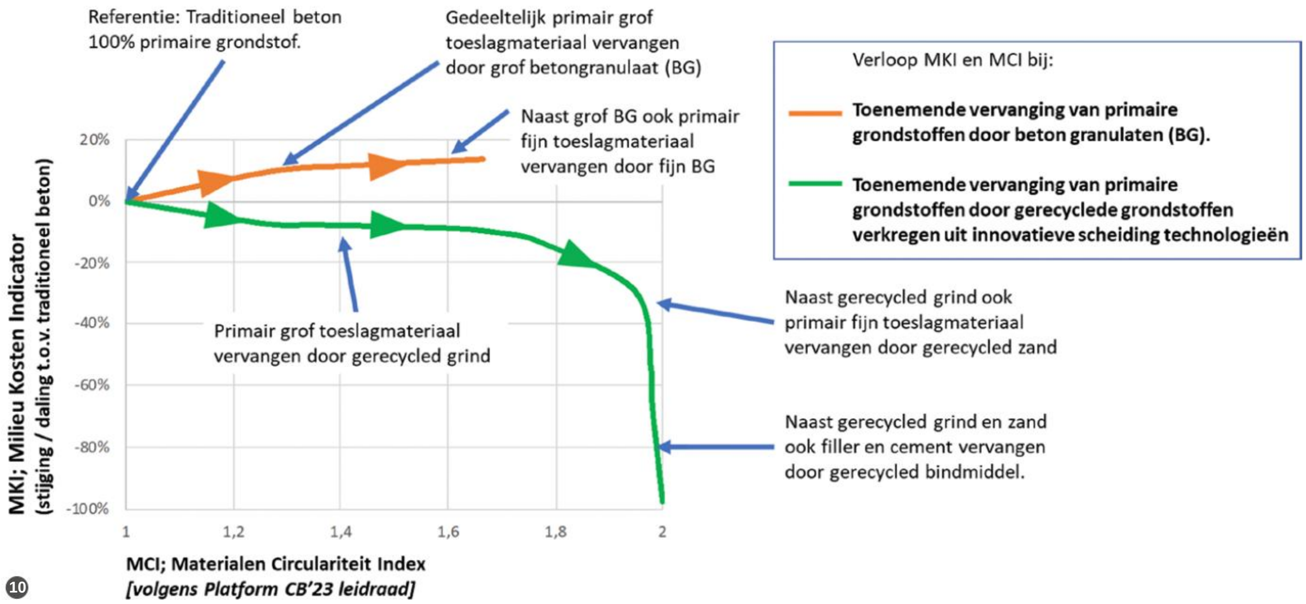
6 ADR Installation, Photo: GBN
7 Result of the C2CA crushing and separation process, photo: Cees Steendijk

8 Mangeler method, photo: Two "R" Recycling Group
9 Result of the crushing and separation process Mangeler, photo: debrisrecycling.nl



river gravel, granite or limestone, but also in terms of binding agents such as port land cement and/or blast furnace cement). This complicates its high-quality reuse in relation to performance properties.

In summary, the essence is that high-quality reuse – with equivalent properties as may be assumed to primary raw materials – stands or falls with a good determination of properties, source separation and their inspection at the start of the process. A logical consequence of this is that, in the long run, the current standardization and certification will have to be implemented be revised to meet this new quality meet demand.

What does it bring?

The use of traditional concrete granulate, both coarse and fine, is a proven method for (partially) replacing primary raw materials with secondary flows. However, preserving performance (quality/technical lifespan) is a critical point of attention in this respect and, moreover, the reduction of environmental costs (ECO) is (very) limited.

High replacement rates can lead to the opposite effect: the CO2 out impact and thus the MKI value will even increase due to the need for more cement. And it must be taken into account adaptation of constructive calculation rules. Only striving for circularity without re taking into account the effects on MKI and required performance in a broader sense can therefore conflict with the aim of reducing the ultimate environmental impact.

In the case of material flows obtained from innovative recycling methods, it appears that higher replacement percentages (60% fine and 100% coarse) are already possible, without adjusting construction calculation rules and without the need for (extra) cement to maintain the same performance properties. secure. The MKI value can therefore fall sharply, with the additional advantage that with future developments (the further processing of the recovered binding agent) this will increase further and can potentially lead to a fully circular concrete mixture (see fig. 10). .

From the perspective of 100% of the available fractions of the supply of concrete Processing residual flows into new concrete by 2030, only innovative recycling methods offer a chance to help give substance to this.

CONSULTED SOURCES

1 Government-wide program for the Netherlands Circular in 2050.

2 Concrete agreement for sustainable growth, July 2018.

3 Roadmap Reuse of concrete residual flows, 2020.

4 Verweij, M., Recovery of cement from concrete. *Betoniek Magazine* 2020/3.

5 Nedeljkovic, M., Schlangen, E., Fennis, S., Selective demolition of concrete structures. *Cement* 2021/8.

6 CROW-CUR Recommendation 127:2021 Concrete with concrete granulate as fine and/or coarse aggregate.

7 CUR Recommendation 106:2014 Concrete with fine fractions from recycled aggregates as fine aggregate.

8 CUR Recommendation 112:2014 Concrete with concrete granulate as coarse aggregate.

9 Wegen, G.van der, An overview of innovative recycling methods. *Betoniek Magazine* 2020/1.

10 Wolf, M. van der, Responsible circular concrete. *Betoniek Magazine* 2020/2.

11 Broere, P., Verweij, M., Kloetstra, S., Recycling granulate: a reliable raw material. *Betoniek Magazine* 2020/3.

12 Concrete granulate in quality concrete, Betoniek Standaard 17/09.

13 www.ruinrecycling.nl.

14 https://www.c2ca-technology.nl.

15 https://freement.nl/smart-liberator/.

16 https://www.rijksoverheid.nl/ topics/circular economy/ documents/reports/2016/09/14/ appendix-1-the Netherlands-circular-in-2050.

10 Impact recycling on both MKI (vertical axis) and circularity (horizontal axis) with increasing amount of recovered raw materials. Reuse of concrete in the form of concrete granulate (orange line) contributes to circularity, but gives an increase in the MKI at high replacement percentages. When concrete is processed into secondary raw materials released from cement stone and these are applied in a new concrete mixture (green line), a lower EMI will also be achieved with a higher circularity value. Since modern separation technologies are under development, this can potentially even lead to 100% recovered material