

Some 38.5 tonnes of crushed concrete material were incorporated as recycled aggregates into the concrete for 40, 50, and 60 Charter Street (pictured), part of the Wood Wharf Phase 3 development at Canary Wharf, east London

Photo: Dylan Garcia / Alamy Stock Photo

Recycled aggregates in concrete

In a circular economy, recycled crushed waste concrete has an important role to play – not just in sub-base and fill, but as an ingredient in fresh concrete. Andrea Charlson explores when (and when not) to use it





over 90% of the UK's hard construction waste is recycled, typically in unbound applications such as sub-base and fill. Currently, about 5% is used as aggregate in new concrete, but there is potential to increase this proportion.

A number of research projects are exploring ways to enhance the properties of recycled aggregates and expand their use within concrete.

Recycled aggregates produced using current recycling practices do not always behave in exactly the same way as natural stone aggregates. Their substitution must therefore be carefully considered, taking a range of factors into account, such as performance, carbon targets and availability.

As always with circular economy approaches, it is essential to take a whole-system view, balancing material properties and environmental impacts, to determine the most appropriate solution. Seeking advice from suppliers early in the process can be beneficial for achieving this balance.

What are recycled aggregates and how can they be used?

The British Standard on concrete specification, BS 8500, differentiates between recycled aggregate and crushed concrete aggregate.

Recycled aggregate (RA) is often used as a catch-all term, and is defined as "aggregate resulting from the reprocessing of inorganic material previously used in construction". There are very few limits on its constituents and its composition can vary considerably.

Crushed concrete aggregate (CCA), on the other hand, must be composed of at least 90% concrete. This results in a more consistent product, which is much simpler to use in a range of potential applications.

Both RA and CCA can be classified as either coarse (greater than 4mm in diameter) and fine (less than 4mm) aggregates.

Coarse CCA is generally uniform enough to be introduced into most concretes with minimal additional assessment. Although BS 8500 does not exclude the use of fine CCA, fine RA or coarse RA, they are more variable, so satisfying the standard requires project-specific testing to confirm performance.



In practice, when discussing recycled aggregates in concrete, this generally refers to coarse CCA.

The Concrete Centre document “Specifying Sustainable Concrete: Aggregates” provides further details of definitions and constraining criteria for use in concretes.

How do recycled aggregates affect structural performance?

CCA is a combination of the original natural aggregate and the residual hardened cement paste from the first use. As such, it affects the performance of concrete in a number of ways.

BS EN 1992-1-1:2023 Annex N: Recycled Aggregates Concrete Structures lists a number of different properties used in the design of concrete structures that may need to be adjusted when recycled aggregates are used. These include compressive strength, shear resistance and deflection calculations. The UK national annex, when published, will provide guidance on exactly how these properties should be adjusted, based on the use of coarse CCA, and it will make reference to the need for testing when using fine CCA, fine RA and coarse RA.

It is important that the use of recycled aggregates is discussed with the whole project team and that they are not specified in isolation without considering their impact on performance.

Recycled aggregate and embodied carbon

Counterintuitively perhaps, recycled aggregates do not necessarily lower the embodied carbon of concrete, and they can increase it.



Photo: Canary Wharf Group

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At Canary Wharf Group and Kadans Science Partner's One North Quay development in London, the team recovered 2,500 tonnes of crushed concrete material from the demolition of a 100-year-old piled quay structure – shown stockpiled prior to being crushed



There are a couple of reasons for this. First, because some recycled aggregates are more absorbent than natural aggregates, this can increase the amount of water required in the concrete, with the knock-on effect of increasing the cementitious content, the predominant source of concrete's carbon emissions.

Secondly, sorting demolition material, and ensuring that it conforms to standards, involves more processing than is required for natural aggregates. For this reason, recycled aggregates typically have a higher A1-A3 (cradle to factory gate) embodied carbon value than natural aggregates extracted from quarries.

One positive carbon aspect for recycled aggregates is that they may be available closer to concrete production sites than natural aggregates (see table below). In these cases,



How transport distances affect embodied carbon

	Cradle to gate (A1-A3) kgCO ₂ e/tonne	Total transport distance by road in km	Transport (A4) kgCO ₂ e/tonne	Total kgCO ₂ e/tonne
Recycled aggregate	6.05	0	0	6.05
Natural aggregate	4.36	19	1.69	6.05
Recycled aggregate	6.05	20	1.82	7.87
Natural aggregate	4.36	39	3.51	7.87
Recycled aggregate	6.05	40	3.65	9.70
Natural aggregate	4.36	59	5.34	9.70

The table illustrates the potential impact of transport on the embodied carbon of natural and recycled aggregates, and the relative distances that each would have to travel to reach the same embodied carbon, irrespective of its use.

The following carbon factors have been used, sourced from the Inventory of Carbon & Energy (ICE) V4.0 database:

■ Natural aggregate from virgin land-won resources, bulk, loose: 4.36kgCO₂e/tonne

■ Recycled aggregate, no heat treatment, bulk, loose: 6.05kgCO₂e/tonne

■ Transport by road, 33t articulated per tonne-kilometre: 0.0912kgCO₂/tkm

Recycled aggregates often travel shorter distances than natural aggregates, with some being processed on site during concrete production. The table shows that when recycled aggregates are sourced at least 19km closer than natural aggregates, they will have a lower A1-A4 embodied carbon.

they may have a lower embodied carbon, after transport is included. Suppliers will be able to advise on the implications and optimum balance for a specific application.

Displacing demand

Recycled and secondary aggregates already make up 30% of the UK aggregates market, using over 90% of UK construction and demolition waste. This means that specifying recycled aggregates in concrete does not necessarily reduce extraction of natural aggregates – it may just divert material from applications where it can be used more effectively.

It is recommended that recycled aggregates are only used in concrete when they are more locally available than natural aggregates, or can be delivered using low-carbon transport. The greatest opportunity could be on urban and suburban sites, where less backfill is needed and there is more likely to be a surplus of demolition waste. These sites are also usually further from extraction sites producing natural aggregates.

Innovations

A number of initiatives are exploring alternative high-value applications for recycled aggregates, to expand their potential use and exploit their ability to absorb carbon dioxide.

Accelerating carbonation

Concrete naturally absorbs carbon dioxide throughout its lifetime, reabsorbing some of the process

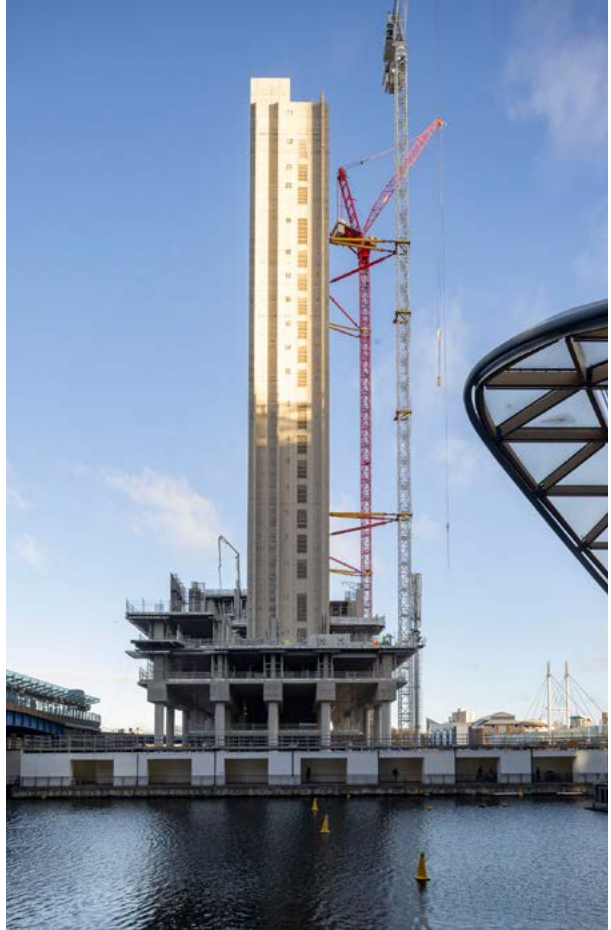


Photo: Canary Wharf Group

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The Wood Wharf project pioneered the injection of carbon dioxide into the remaining demolition concrete from the quay, using technology developed by Neustark to enable permanent carbon sequestration. These carbon-negative aggregates were used in temporary works structures for the construction of One North Quay (pictured)

emissions from cement manufacture, and acting as a long-term carbon sink. This occurs slowly during a structure's service life, and much more quickly when it is demolished and the concrete crushed, increasing the surface area. A number of innovative solutions are exploring ways to accelerate or increase this ability, through specialist crushing techniques and by curing CCA with carbon dioxide in a form of carbon capture.

There are suggestions that these techniques also improve the properties of the aggregate, potentially reducing water demand. This in turn removes the need for extra cement and can lower the embodied carbon of the resulting concrete.

Recovering concrete fines

Techniques are being developed to separate concrete back into its constituent parts, effectively deep-cleaning the aggregate by mechanically removing the hardened cement. The Mineral Products Association is part of a research team looking into the technical potential of the resulting material, which is known as recycled concrete fines (RCF) and can be used to make new, lower-carbon cement or as a supplementary cementitious material.

The additional processing necessary to produce RCF may also result in a cleaner coarse CCA, which could in future be determined to perform closer to a natural aggregate.

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Visualisation: Canary Wharf Group

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CGI of One North Quay. Designed by Kohn Pedersen Fox, it is set to be Europe's tallest purpose-built commercial laboratory building