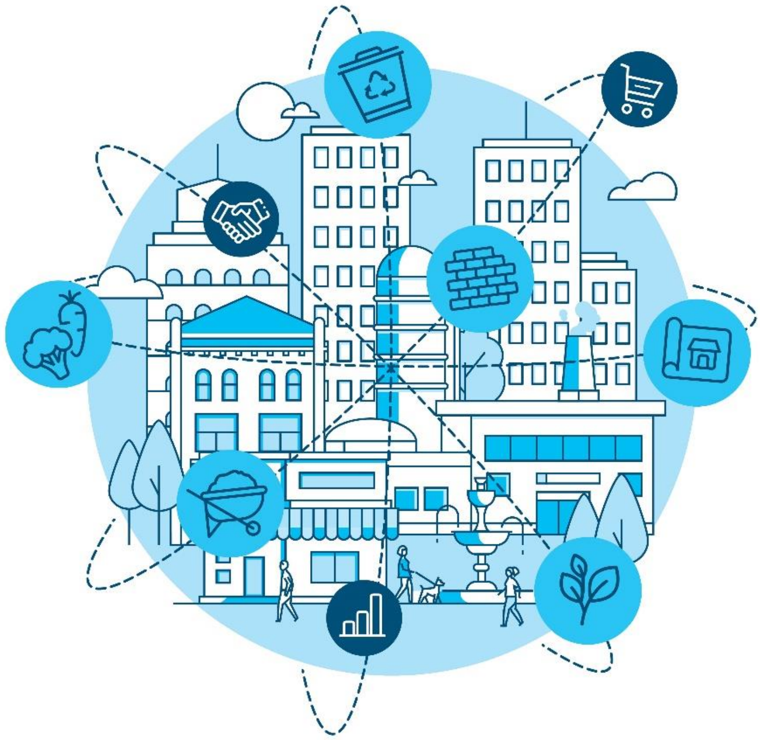
Recycling concrete in Roskilde

Extract from the Demonstration Report

Municipality of Roskilde, Denmark



Contents

This text describes Roskilde’s experience in recycling concrete in a car park construction. The sections come from Roskilde’s CityLoops demonstration report available here.

Car park 1 “Indfaldet”

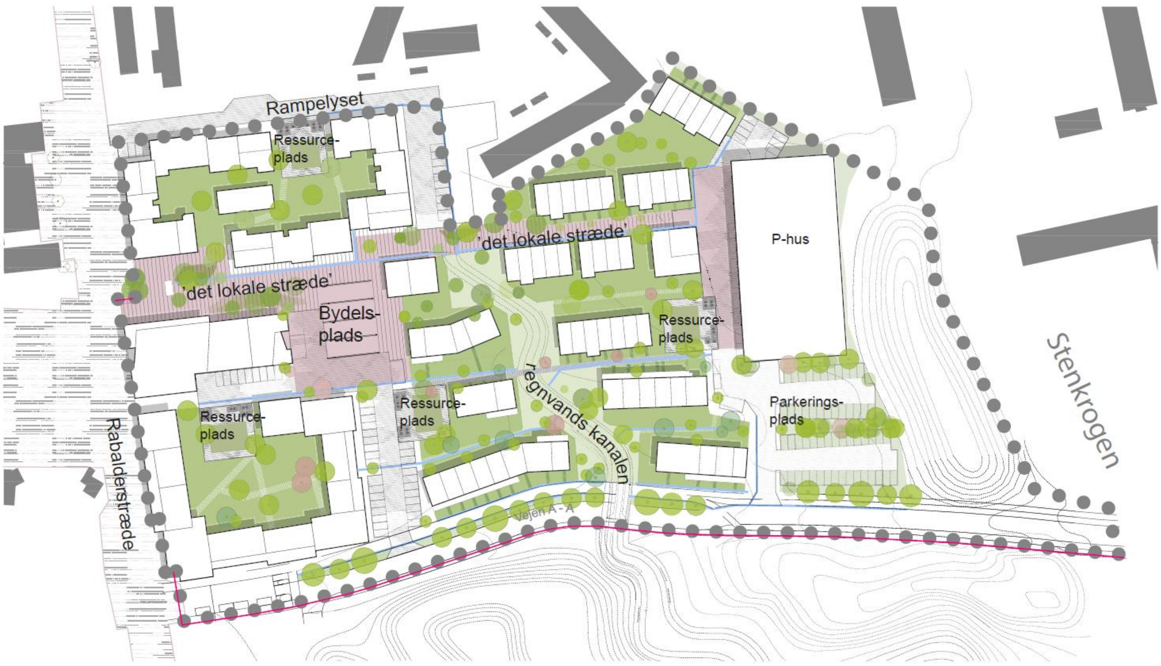
Construction of Car Park Indfaldet was finished in mid-2021. When the building authority started digging in preparation for the car park, we discovered a large amount of concrete obstacles in the ground stemming from the site’s concrete production function in the past. The concrete unearthed was kept on site and crushed into a mixed fraction. The mixed fraction was used for material layers below the construction, replacing virgin gravel. Other concrete recovered from the digging was cleaned and crushed, to be mixed on site and used as aggregate in new concrete. This has made a very positive business case.

A criterion in the tender for the new car park was that the developer foresee design for disassembly, including scenarios for future recycling. Consequently, a report was delivered by the contracted developer (MT Højgaard). They created the multi-storey car park with a steel skeleton, premade components assembled by bolts and a minimal use of concrete. They made calculations on CO2 for future reuse/ recycling and have documented the benefits on future use of materials from the car park. The local Parkour club is to finish/ furnish their area of the Car Park Indfaldet with materials from the material bank at Musicon.

Early Planning and local plan

In early 2017 it was politically decided to develop an area located near the east border of Musicon in Roskilde. The area under the name “Indfaldet” was planned in Local Plan 660 for Roskilde.

The purpose of the local plan is to secure the framework for a new quarter at Musicon with a total of 46,000 floor meters divided into mixed residential types, office businesses and public-oriented functions. Part of the local plan was the parking facility “Indfaldet” with approx. 240 parking spaces to serve approx. a quarter of the entire district. The parking facility includes one multi-storey parking garage and parking on the ground.



The local plan stated that it was desirable that new developments in Musicon would build on the area's identified as an innovative urban area with experimental construction and clear industrial traces. It is therefore part of the purpose of the local plan that new buildings have an experimental and characterful expression. The illustration plan shows the overall layout of “Indfaldet".

Planning

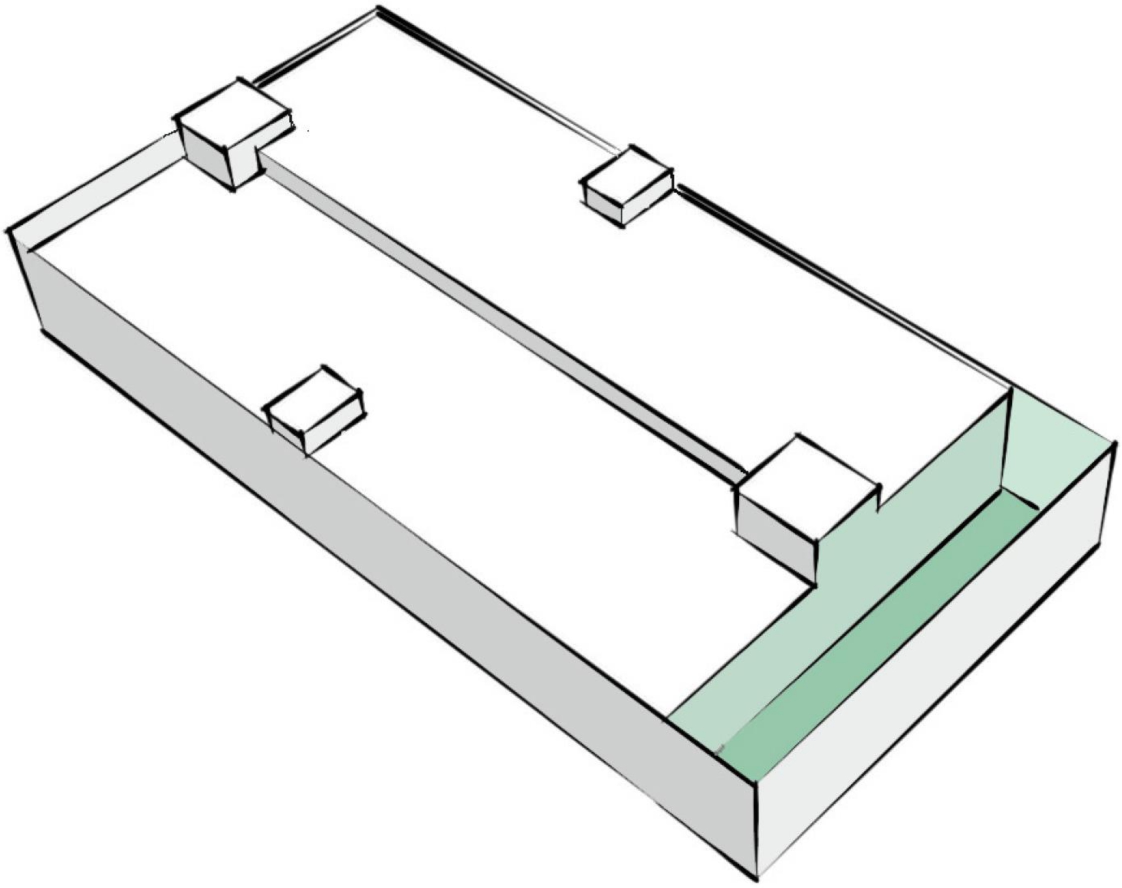
After approval of the local plan 660 in August 2018, planning of the Multi-storey Car Park “Indfaldet” was handed over to the building department in the municipality, where practical planning of the Car Park started in late 2018.

Musicon already offered a great variety of activities for especially young people, but most of these activities were placed in outdoor facilities. Therefore, it was decided in the steering group of the car park, that the house should hold possibilities for other activities than parking. This decision was underlined by the fact that other car parks in the municipality had suffered a great deal of unwanted activities, especially at night. The hope was that inviting other activities into the car park would create a sense of ownership in the house, that again would be translated into caretaking of the place.

As a starting point, a traditional car park with 2 floors above ground was desired, as well as parking on the roof with space for around 250 parking spaces. To the south, an area for activities other than parking was desired. This area is referred to as "Indskydelsen" in this program. The "Indskydelsen" can be understood as an area that is inserted between the main structure of the car park and the facade to the south. This area allows alternative functions to be envisaged at the southern end of the house.

In illustration 01, the “Indskydelsen" is marked in light green. Roof elements above the Deposit are not shown in the illustration.

Illustration 01



The planning for car park “Indfaldet” was started by gathering all available information on previous soil surveying in the area. As part of the strategy for Musicon environmental testing had already been carried out and the results showed that large amounts of soil contamination could be expected in the area of the car park. Therefore, the environmental department in the municipality was contacted and the need for further surveying was established. As part of the environmental documentation for the car park an approval according to the regulations of §8 in the national soil pollution act.

According to § 8 of the Soil Pollution Act, the developer must apply for a § 8 permit when excavation and construction work is carried out on most mapped plots. The permit is called an §8 permit, as the provision is in §8 of the Soil Pollution Act. The application for the §8 permit is sent to the municipality where the activities are carried out, where the application must contain as much concrete information as possible about the upcoming project.

This information would normally be handed over to a turnkey or general contractor, who then would apply for necessary permits (amongst those §8), as part of the building procedures. However, in the case of the car park, the preliminary testing of the soil already has shown a high amount of different complexities. For instance, there had been shown high levels of gas in the underground due to old deposits of organic landfill. The presence of underground gas would trigger special measures to prevent ignition of trapped pockets of gas underneath the building.

But most significantly there had been discovered a large amount of concrete obstacles in the ground stemming from the site's concrete production function in the past.

Procurement strategy

Both the presence of underground gas and concrete obstacles would lead to a high risk for the contractor, since he would be locked to a fixed timetable in his contract with the municipality. This risk he would need to cash in in his offer to the municipality. The conclusion was straight forward. If the municipality could apply and receive a §8 approval in advance of the tender, a big risk would be lifted from the tender to the builder and thereby ensure a better price. This practice has later led to a new procurement strategy in the building department where three elements are always contemplated in advance of deciding where a risk shall be placed in a building process, namely risk, responsibility and consequences. This procurement strategy will be folded out under "Circular procurement strategy".

It was decided to carry out the tender as a turnkey contract. According to The Public Procurement Act No. 1564 of 15 December 2015, the contracting authority can set the price or costs to ensure that competition is carried out based on qualitative criteria only. When deciding to carry out a competition based on qualitative criteria only, it gives the contracting authority an advantage in communicating the wishes for the building more effectively, compared to competition, where price is the main focus. This is due to the fact that when carrying out a competition you have to balance demands and incentives in the tender. Demands typically come in the form of very specific descriptions for function or materials. But demands will often be interpreted by the market as minimum requirements and the overall quality of the building can be lowered. Incentives on the other hand come in the form of award criteria, where the award criteria will be interpreted as the main interest of the building authority, and thereby will receive more attention by the bidders.

The balance between demands and award criteria is crucial when communicating your ambitions and prioritisation as building authority. Demands are equal for all bidders, whereas award criteria are answered differently by each contractor/bidder and the specific solution chosen by the contractor subsequently comes with ownership and responsibility.

Underlining the wish to focus on quality and not price, it was decided to carry out the tender as a competitive procedure with negotiation according to The Public Procurement Act Section 61 -66. A competitive procedure with negotiation means that the contractors will be participating in bilateral negotiations with the building authority after handing in a preliminary offer.

Tender

An advisor was hired for the continued planning and surveying in relation to obtaining a §8 permission in advance of the tender. The advisor laid out a timetable for the tender in close collaboration with the building authority.

- The process started in October 2019 where all applications for attending the bidding, should be handed in.
- In late November an information meeting was held with all interested contractors. In the meeting the overall scheme for the bidding process was presented.
- In early January 2020, there was a deadline for presenting questions before the negotiations started.
- By mid-January 2020 preliminary offers should be handed in and in late January the negotiation meetings would start.
- By the end of February, the final offer should be handed in and mid-March the contractors who handed in offers would be informed of the result. By law a stand still period follows the communication of the winner, and in this case, it would end in late March 2020.
- By early April it would be expected to have a contract with the winning contractor. Immediately after signing the contract the contractors' planning could start.

After creating the tender time schedule, work on the remaining part of the bidding materials was started. A number of very central documents was created, amongst those was the technical programme, where all demands for function and materials are listed. An architectural programme where all the aesthetic demands were listed along with the description of the wanted place, atmosphere and relation to the future users. A sustainable strategy, listing all objectives for sustainability.

Overall, the construction must provide the best conditions for Car Park Indfaldet to fulfil its purpose and at the same time contribute to sustainable development locally. This is expressed in the following focus areas:

- We wanted a building where conscious, sustainable choices have been made within all aspects. Life cycle calculations must be thought into the project both in relation to maintenance and operating economic solutions as well as in aesthetic considerations. The building must be robust and durable with the focus that good architecture creates satisfied users and lasts further. This is documented for instance through an account of the total economy, which submitted in connection with offers, total economic assessments in connection with change projects, and preparation of a total economic calculation in connection with the delivery.

- A building with a low environmental impact was desired. Therefore, life cycle assessments had to be considered in the project both in relation to the choice of materials and the design of solutions as well as in aesthetic considerations. This should be documented for instance through an account of life cycle assessments with a focus on CO2, which is submitted in connection with offers and preparation of life cycle calculation in connection with main project.
- With its local roots and voluntary efforts, the house is a socially sustainable project with accessibility for everyone and space for the community. The interior design of the house must support this function with the possibility of variation in use. The layout is crucial for a building's functionality and flexibility different uses. These factors play a decisive role in the building's performance spatial and architectural quality and will also be reflected in the building's value stability. Functionality and flexibility also affect user satisfaction with the building. A flexible building that can be changed over time is desired. The addition of P-hus mod south must be able to change its use to the greatest extent possible and be used for several purposes. As well as being too prepared for 100% conversion to electric cars.
- In order to best promote the recycling of valuable materials in the waste shell, it is taken into account that the building parts can be easily separated and sorted. It is done best if the actual separation and sorting is thought of already in the design phase, and materials and components are mounted independently of each other as far as possible. On in the same way, removed components and materials must be treated with a view to ensure recycling of the highest possible quality, i.e., with the least possible environmental impact and best use of resources in the recycling process.
- Recycled concrete must be used in connection with in-situ casting of new concrete constructions with low environmental class.

Handling risk and securing soil balance in tender and procurement strategy

As part of the tender two rounds of negotiations were held. In the negotiations the topic of the concrete in the ground was taken up and the contractors had to describe how they would overcome the possible obstacles they would meet in the ground. Normal procedure for the contractor would be to stop the work and wait until an agreement of removing the obstacles was achieved. This normally is a risk that falls upon the building authority, since the contractor does not have any possibility to evaluate the costs before the actual amount is known. Each of the bidders were asked to describe what they would do in advance and how they would handle the situation in the building process.

The winning contractor described that they would reinforce the tips of the pile foundation and that they would dig trenches 1 metre deep in order to guide the piles better. Secondly, they described that, if obstacles were met, they would contact the building authority and the problems would be observed and solved in partnership.

A criterion in the tender for the new car park was that the developer implemented design for

disassembly, including scenarios for future recycling. Consequently, a report was delivered by the contractor (MT Højgaard). They created the multi-storey car park with a steel skeleton, premade components assembled by bolts and a minimal use of concrete.

One of the main objectives in the procurement of the multi-story car park was to maintain as much soil as possible on site. Through our participation in City Loops we have established that the CO2 associated with moving soil is considerable, and therefore the savings potential when keeping soil on site is also considerable.

For this reason, we had a large incentive to address the issue in the procurement strategy. We knew in advance from the technical investigation of the site that there was a high risk of concrete waste in the ground on site. The contractor was therefore in the tender obligated to work with an optimal soil balance. The procurement process was therefore the single most enabling factor in maintaining the incentive to keep working for a soil balance and circular solutions.

Dialogue with the contractor and risk assessment in the construction process

In the early dialogue with the chosen contractor, the risks were discussed and a reasonable process for what the contractor should do was agreed upon, the moment he encountered any obstructions in the digging process. The contractor was to immediately stop and together with the municipality project manager regarding the obstruction. Then he was to present an excavation price for whatever amount they had found. (The unit price was agreed upon in advance, in the tender list.)

By having this very close dialogue with the contractor, it was possible to keep the price of the excavation to a minimum.

A normal procedure would have been that the contractor excavated the concrete waste, got it transported away and deposited, and brought new virgin soil and gravel to fill up the remaining pocket. This would also result in time delay, CO2 expenses on the increased transport and not least, an increased price for the builder.

In this case, instead of the above-described normal procedure, the contractor was to contact the builder, agree on excavation, and place the excavated concrete waste just outside the plot. The contractor would then continue with his normal tasks, while the project manager of the builder ordered a crushing contractor to crush and sort the dug-out materials into three fractions. Fine, coarse and mixed aggregates.

When this was complete, the contractor immediately rebuilt these aggregates into the site project. The fine and coarse aggregate was incorporated into new concrete in the ground level floors, and the mixed aggregate was used as bottom protection gravel. The contractor was obligated to do this, as the tender stipulated that he was responsible for keeping soil balance. The complexities and costs associated with the excavated concrete were turned into a benefit for all involved parties. The original period of the project was not altered, as all crushing and rebuilding was kept within this timeframe. The obstacles were found and rebuilt into the site within approximately two months.

In the procurement process, we were very much aware of how the burden of risk lies in the process. Sometimes the price for the contractor to bear certain risks is disproportionately high. The task for the builder is therefore to assess where the elements of risk are naturally handled with greatest benefit for sustainability and price. In this project, the builder undertook detailed investigations of the site in advance, so the risks were uncovered, and the information was available in the tender.

In addition, the responsibility for handling any obstacles remained with the builder, in this case the handling and crushing of the concrete. Having removed this risk from the contractor, and the price agreed upon in advance, the costs associated with this operation was reduced to the price for excavation of any found waste. The contractor's time flow was uninterrupted, he could get rid of the obstacle immediately, and regain the finished product (foundation gravel ready to rebuild) just as easily from the depot next to the building site.

By assuming the risk for obstacles and the task of handling the concrete obstacle, and by requiring the bidders to define the practical procedures in advance, the builder was able to solve the situation with the highest focus on a circular solution, as well as keeping the price lowest possible.

They made calculations on CO2 for future reuse/ recycling and have documented the benefits on future use of materials from the car park.

The crushing itself took place onsite, when all the dugout obstacles were ready outside the building fence. In total an amount of 1087 tonnes of concrete waste materials were placed outside the fence.

As mentioned earlier we knew in advance from the technical investigation of the site that there was a high risk of concrete waste in the ground on site. The whole area of Musicon used be the factory ground of the concrete manufacturer “Unicon” in Roskilde and the concrete waste was placed in the ground from the time when the area functioned as waste pit for the concrete leftovers. The quality of the materials was very diverse, since most of the concrete waste was fail casts and surplus material from the casting of concrete elements in the past.

Therefore, we asked a specialised advisor to visually inspect the dugout materials prior to crushing, in order to determine the potential for using crushed materials in recycled concrete. There were two main conclusions from the inspection. Firstly, there was a high degree of humus contamination in the dugout materials, and secondly a percentage of the dugout materials stemmed from low strength materials such as concrete pipes and pavers. This led to the conclusion that the dugout materials should be sorted prior to cruising into two selections. One selection of bigger pieces of high strength concrete suitable for aggregates in recycled concrete and a selection of the dugout materials that could be crushed to a mixed aggregate for foundation works.

The selection was carried out by the same contractor who was responsible for the crushing itself.

The neighbours were informed about the crushing in advance in an information meeting, held by the contractor on site. The meeting was part of the contractors' obligations to communicate activities to local actors in Musicon in order to prevent unnecessary conflicts due to lack of knowledge of the ongoing activities. In other projects it has shown fruitful to communicate activities, which could give rise to worries, very directly and openly.

After the initial selection of materials, crushing started on site. The crushing itself was carried out by a specialised local company, who had all necessary machinery and materials. For the crushing a track-mounted impact crusher was used (Kleemann Mobirex MR 130 Z) with an attached screener.

The crushing of a total of 1087 tonnes of concrete was carried out over a span of 6 hours. After the crushing the crushed material was screened into three different fractions: 0-16mm, 16-32mm and a mixed fraction.

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Dato	Start	Stop	Eff. knusn.	Rep.	Opstk. bånd	Materiale	Sold	Ton type	Ton
Mandag 16/11-2020			0,00	0,00	Nej				0,000
Tirsdag 17/11-2020			0,00	0,00	Nej				0,000
Onsdag 18/11-2020	10:30	17:00	2,50	4,00	Nej	Beton	40 mm	0-32	390,000
Torsdag 19/11-2020	06:00	14:00	5,00	3,00	Nej	Beton	40 mm	0-32	555,780
Torsdag 19/11-2020			0,00	0,00	Nej	Beton	20 mm	0-16	140,940
Fredag 20/11-2020			0,00	0,00	Nej				0,000
Lørdag 21/11-2020			0,00	0,00	Nej				0,000
Søndag 22/11-2020			0,00	0,00	Nej				0,000
I alt:			**7,50**	**7,00**					**1086,720**

When the crushing was finished the contractor was informed that he could pick up the mixed crushed fraction for foundation works and only the fine and coarse fractions were left. The use of the mixed fraction is standard procedure, and the quality of the mixed fraction is equivalent or better compared to standard stabilised gravel. Procedure described in EN 13285:2018 Unbound mixtures - specifications were followed. The European Standard specifies requirements for unbound mixtures used for construction and maintenance of roads, airfields and other trafficked areas and applies to unbound mixtures of natural, manufactured and recycled aggregates with an upper sieve size (D) from 5,6 mm to 90 mm and lower sieve size (d) = 0 at the point of delivery.

During the progress of the building, we discussed how to reintegrate the two fractions. It was decided to use them in the concrete floors in the lower part of the building, since demands for strength in this type of construction are low and the consequences of a possible failure are very small. The standard build-up of floor constructions on ground is levelling the ground placing insulation plates of EPS, placing reinforcement net and pouring concrete mixture onto the insulation and reinforcement. This means that the load bearing capacity of the surface is directly connected to the ground and a smaller failure in the concrete will not have any significant consequence for the strength of the concrete deck itself.

As part of the preparation the two crushed fractions were tested for particle density and water absorption by the special technical consultant according to EN 1097-6. (Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption)

PELCON

Korndensitet og vandabsorption (DS/EN 1097-6)

Udført af: SGP

Sagsnr. 21-043a

Prøve-ID	Densitet, tilsyneladende [Mg/m^3]	Densitet, VOT [Mg/m^3]	Densitet, tør [Mg/m^3]	Absorption [%]
1	2,61	2,41	2,29	5,3

Modifikation af metode: Prøven er ikke sigtet på hhv. 4 mm og 31,5 mm-sigte og er vandmættet i >24 timer.

Based on the tests and using earlier developed guidelines for mixing concrete using recycled aggregates. Parts of the guideline is described later in this document and is a more general guideline for mixing concrete using recycled aggregates.

The municipality asked a local contractor who has specialised in on site mixing of concrete, to assist us in the process. On the day of the mixing the contractor came with a mobile mixing plant that was already loaded with cement and water. The building contractor then helped with loading the two crushed fractions onto the mobile mixing plant. The mixing followed specific mixings recipes given by the special consultant.

When the mixture was ready it was poured onto the insulation and reinforcement and levelled by hand.

NOTE Guidance on the effects of alkali-silica reactivity, is given in annex G.

5.8 Classification of the constituents of coarse recycled aggregates

The proportions of constituent materials in coarse recycled aggregate shall be determined in accordance with prEN 933-11 and shall be declared in accordance with the relevant categories specified in Table 20.

Table 20 — Categories for constituents of coarse recycled aggregates

Constituent	Content Percentage by mass	Category
Rc	≥ 90	Rc_{90}
	≥ 80	Rc_{80}
	≥ 70	Rc_{70}
	≥ 50	Rc_{50}
	< 50	$Rc_{Declared}$
	No requirement	Rc_{NR}
Rc + Ru	≥ 95	Rcu_{95}
	≥ 90	Rcu_{90}
	≥ 70	Rcu_{70}
	≥ 50	Rcu_{50}
	< 50	$Rcu_{Declared}$
	No requirement	Rcu_{NR}
Rb	≤ 10	Rb_{10-}
	≤ 30	Rb_{30-}
	≤ 50	Rb_{50-}
	> 50	$Rb_{Declared}$
	No requirement	Rb_{NR}
Ra	≤ 1	Ra_{1-}
	≤ 5	Ra_{5-}
	≤ 10	Ra_{10-}
X + Rg	≤ 0,5	$XRg_{0,5-}$
	≤ 1	XRg_{1-}
	≤ 2	XRg_{2-}
	Content cm^3/Kg	
FL	≤ 0,2 [a]	$FL_{0,2-}$
	≤ 2	FL_{2-}
	≤ 5	FL_{5-}

[a] The ≤ 0,2 category is intended only for special applications requiring high quality surface finish.

In the following you can read a chronological review of all the processes associated with production of recycled concrete. Each process is described as concrete and simple as possible. The description is valid as a general guideline for handling, crushing and mixing recycled aggregates.

Concrete flow

Control and monitoring

The production of recycled concrete involves several crucial processes such as crushing, welding, and pile building. These processes require specialized skills and abilities. It is crucial to have experienced individuals who are specifically knowledgeable in this field to manage and supervise the work, rather than relying solely on those with experience in general industrial concrete production. There are numerous potential issues that can arise and must be avoided. Even a small error, such as using an incorrect substrate or operating a soldering plant on contaminated soil, or a brief 10-minute mistake in handling with a front loader, can result in the destruction of an entire production of recycled aggregate.

The crushing of 1,000 tons of concrete can be completed in just half a day, and the subsequent welding process takes approximately the same amount of time. Therefore, the time required for monitoring and overseeing the process is relatively limited.

Examination of concrete before demolition

Prior to demolition, it is important to conduct a thorough examination of the concrete structure to assess its condition and identify any damages. Simultaneously, it is advisable to separate the concrete into different structural parts. Following this, the concrete quality is assessed through the process of drilling cores, examining their quality, and determining the potential for recycling.

It is crucial to also consider the environmental conditions during the demolition phase. This includes effectively managing dust and noise in compliance with the environmental regulations and guidelines stipulated in the relevant municipality's environmental activity order. Further information on contamination studies of the concrete to be demolished can be found in the "Investigation of waste types" section.

New edition of DS/EN 206 DK NA:2020 (Concrete - Specification, performance, production, and conformity)

As of January 1, 2021, a new edition of DS/EN 206 DK has been implemented, which has implications for the utilization of recycled aggregate in concrete. According to this edition, provided that specific requirements are met, the following is now permissible: It is now allowed to replace 100% of both fine and coarse aggregate with recycled aggregate.

Recycled concrete can be used in all exposure classes. From January 1, 2021, a dispensation from the municipality is no longer required. Recycled aggregates that meet the requirements can be used interchangeably with traditional aggregates.

The key requirements for recycled aggregates are outlined in DS/EN 206 DK NA:2020, section E.3.3, as follows: These requirements pertain to recycled aggregate, as well as crushed process aggregates used by a group of concrete manufacturers in quantities exceeding 5% of the total aggregate quantity, as mentioned in point E.3.2.

Recycled aggregate must originate from concrete structures. Aggregates from concrete products such as pipes, well materials, concrete products, paving stones, aerated concrete, lightweight clinker blocks, and plaster and mortar from masonry constructions should not be used in the production of recycled concrete. However, concrete with cement and aggregates that meet this standard may be used. In case of any uncertainty, it must be documented that the concrete is composed as structural concrete.

Aggregates for recycled concrete

Crushed concrete serves as an excellent aggregate material for the production of new concrete, provided that the material is deemed "healthy," well-documented, declared (in accordance with DS/EN 12620), and meets the applicable requirements for recycled aggregates as per DS/EN 206 DK NA. Once the desired maximum stone size (D_{max}) has been established, taking into account the specific use of the concrete, such as reinforcement and cover layer requirements, the crushing and soldering processes can commence. Piles of recycled material, consisting of sand (0-4 mm) and stone (traditional fractions or a wider range, e.g., 4-25 mm), can then be built up.

Once these bunkers are ready and the documentation is in order, the recycled material can be utilized in concrete production in the same manner as natural aggregates. This means that it can be incorporated into concrete mixes according to the desired specifications and requirements.

Crushing

The concrete is typically crushed using either a cone crusher or a jaw crusher. The desired size for the crushed material is usually 0-32 mm, as this categorizes it as stable gravel KVII according to DS401 standards. It is essential to ensure that the operator responsible for the process is knowledgeable in handling crushed materials intended for reuse.

Some operators prefer to combine the crushing and soldering processes in a single operation using a crushing plant with separate soldering capabilities. However, most operators choose to perform the soldering process separately, as it provides flexibility in disposing of certain parts of the crushed material, such as using them as road fill or for similar purposes. This approach allows for greater versatility in utilizing the crushed material effectively.

Soldering

The soldering process for the crushed concrete can be done on two separate sieve sizes: 6 mm and 28 mm. In the experimental project at Musicon, the 1,000 tons of crushed concrete (0-32 mm) were divided into three piles: 0-4 mm, 4-25 mm, and 25-32 mm. However, the pile with 25-32 mm sand was not used in the concrete production at Musicon.

After soldering, representative samples need to be taken from the piles intended for concrete production (specifically, the stacks of 0-4 mm and 4-25 mm). These samples are used for a comprehensive aggregate analysis in accordance with DS/EN 12620 standards. It is important to conduct density and absorption determinations using a modified method (refer to Appendix 2), while other tests for recycled aggregate can be carried out as specified in DS/EN 12620.

Experience has shown that new concrete with recycled aggregate often exhibits improved properties in fresh concrete, attributed to better grain shape and lower density. When crushing concrete, the aggregate material naturally divides into stone fractions that can be directly used in new concrete, eliminating the need for additional soldering. Consequently, a single silo for stone aggregate is sufficient for subsequent concrete production.

Recycled aggregate has a higher absorption rate than natural materials due to the presence of cement paste. Finer crushed concrete contains fewer natural stones among the grains, resulting in higher porosity and absorption. As a result, crushed concrete takes a significantly longer time to become saturated with water, often taking days, compared to natural materials. If the recycled aggregate (crushed concrete) is not saturated with water, it will absorb moisture from the concrete during mixing. This can significantly reduce the workability of the concrete immediately after mixing, leading to potential issues with casting and durability.

In Denmark, where autumn weather brings abundant rain, the material piles typically become waterlogged naturally. However, during dry periods (especially in summer), it may be necessary to water the piles, for example, using a garden sprinkler. Just like in any concrete production, the free moisture content in the aggregates should be determined before commencing the concrete production process.

In the case of mixing recycled concrete in "Indfaldet," the contractor neglected to measure the amount of water in the stored aggregates. Consequently, lumps of dry material formed during mixing and had to be manually removed.

It is important to note that crushed concrete requires a significantly longer drying time than natural aggregate to accurately determine the moisture content.

Mobile mixing plants

Normal/small mobile mixing plants have a smaller production capacity compared to factory-made concrete, which is why precast concrete typically holds the exclusive right for large castings. However, for productions below 25 m3 of concrete per hour, normal/small mobile mixing plants can effectively handle the task, provided there is sufficient space on the construction site and the work can be carried out without causing disturbance to neighbouring areas in terms of dust and noise.

Operating a mobile mixing plant requires the involvement of a minimum of three personnel:

- A certified and experienced mixing master who oversees the concrete mixing process and ensures the proper blending of materials.

- A person operating an excavator/front loader for continuous filling of the open material silos, ensuring a steady supply of materials.
- A concrete laboratory technician responsible for testing the fresh concrete, including measuring set dimensions, air content, and temperature. This technician also performs casting and moulding of items for pressure testing.

These three individuals collaborate to ensure the smooth operation of the mobile mixing plant, maintaining quality control and meeting the necessary standards for the produced concrete.

Handling of concrete on mobile mixing plants

Overall, there is no difference between factory concrete and concrete produced on a mobile mixing plant. Also on a mobile mixing plant, the concrete delivery must of course be adapted to the casting technique and speed, so that the contractor's expectations and the production capacity match. In connection with handling the concrete, however, there are a number of conditions that are different:

- The concrete is produced and delivered in small loads – typically 1m3.
- The emptying height under the mixer requires the use of a flat crane bucket without stocking and emptying device — in other words, the low crane bucket must be tipped when emptying.
- Driving via belt directly into a traditional crane bucket is not recommended for concrete with a high set point, because the concrete risks de-mixing.

- The concrete in the low crane bucket must be driven and lifted by a separate vehicle – e.g., front loader/Manitou.
- The flat crane bucket can fill the concrete directly the pump when casting high walls.
- Use of two crane buckets (one flat and one traditional with stocking) makes it easy to fill the concrete in the form with moulding of moderately low walls.
- Using two crane buckets (one flat and one traditional) does the concrete is easy to place when pouring floors and all-terrain tires.

Receipt optimization and mobile mixing plant

To ensure the desired properties of concrete, including workability, strength, and durability, a suitable concrete recipe must be determined for all concrete production, including recycled concrete. This process involves a combination of experience, laboratory testing, casting of standardized specimens, and verification of strength and durability properties.

Since concrete requires at least 28 days to fully develop strength, casting of test specimens begins well in advance, typically at least 1 ½ months before the concrete is to be produced. This allows for sufficient time to assess the strength and durability characteristics of the concrete.

Setting up and calibrating a mobile concrete mixing plant typically takes at least half a day, and the process of transferring and running in a concrete recipe requires a similar amount of time. During this preliminary work, it is common to produce 3-6 m³ of concrete that cannot be included in the actual production. This excess concrete must either be disposed of or used as filler if suitable opportunities arise.

These measures are essential to ensure that the concrete produced meets the required specifications and performs as expected in terms of its properties and durability.

LCA calculations on recycled materials and design for disassembly

The trial project at Musicon has been joined by an online CO2 - calculator that can help you set figure on the potential CO2 -saving that is connected with your specific project. This means you can look on your own project's potential to save CO2 – instead to look at average figures for discharge.

Before you can use the calculator to assess the environmental benefits of recycling concrete on a given construction project, you must obtain a number of information and data. You must, among other things, be able to put numbers on that amount of crushed concrete that is available – or can be expected to be available – and you must also know the distances for gravel pit, site for landfill, recycling site and name of concrete supplier. Once these data are in place, you can use the online CO2 - calculator to calculate the amount of CO2 - emissions that you can save the environment for, if you choose to reuse concrete on your construction project.

The calculator is based on the three recycling levels, A, B and C, described earlier, and compares the three recycling levels with use of traditional mobile concrete for in situ casting as reference value for CO2 - the discharge. During the development of CO2 - we have focused on the calculator on providing a sufficiently uniform data basis for the two different processes (in situ casting with recycled aggregate material vs. the more traditional process with allocated concrete production and transport to construction site for in situ casting with new concrete). The concrete recipe (the content of cement and aggregates) has therefore also been the same in both processes. Since it is a tool for calculating CO2 - the savings potential, takes CO2 - the calculator does not height for the entire life cycle of each of the two processes, but concentrates only on the elements that differentiate the two processes. It is therefore important to emphasise that that CO2 - the calculator does not replace the need to make LCA calculations with dedicated tools, such as LCA build. LCAbyg is the market standard for LCA calculations in DK and can be downloaded for free at https://www.lcabyg.dk/.

It is a basic prerequisite for CO2 - the calculator that it not only uses generic data from various sources, but to an equal extent is based on project-specific data such as the distance to the landfill and the amount of crushed concrete. This means that the comparison between recycled concrete and mobile concrete - and their respective CO2 -discharge – is not static and therefore can never be seen as a general recommendation. So, it is only when you allow the project-specific data to be included in the calculation, that you can use the result to assess whether recycling is the right solution.

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and bio-waste, where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and bio-waste, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

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