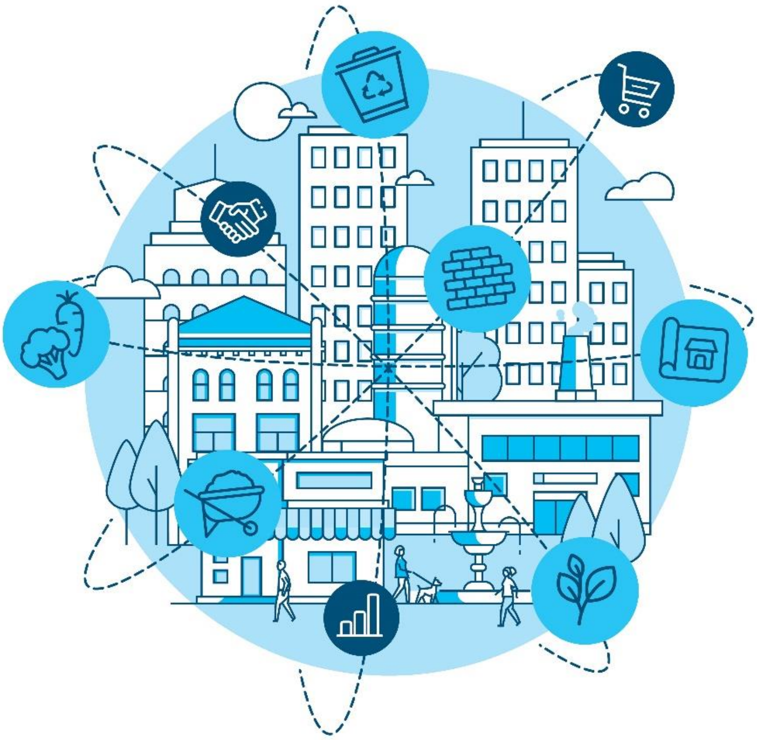
Business case in Mikkeli 2

Description - Reuse of concrete aggregate in concrete production

Mikkeli, Finland



Contents

This text describes Mikkeli's business case in the Reuse of concrete aggregate in concrete production. The sections come from Mikkeli's CityLoops demonstration report available here.

Reuse of concrete aggregate in concrete production

About 20000 tons of concrete demolition waste is received at the municipal waste center in Mikkeli, operated by the municipal waste company Metsäsairila Ltd. It is currently crushed by a contractor and used in maintaining the landfill roads and other earthworks on the premises. This can be classified as down-cycling of the concrete waste because it could have higher value recycling possibilities. On the other hand, without access to this material Metsäsairila would have to buy natural aggregates for landfill maintenance.

Occasionally the crushed concrete has been used for road construction. In 2019 5800 tons of recycled aggregate was used by Mikkeli in building the access road to the waste center. The process was conducted following the Government Decree 843/2017[1]. In 2020 134 tons of recycled aggregate was used by Metsäsairila Ltd. in constructing a rural waste transfer station in Rämälä. In 2021-2022 no such recycling activities were conducted by Mikkeli municipality[2].

Inspired by several demonstration actions in Denmark and information exchange within CityLoops project, the CityLoops team in Mikkeli decided to study the feasibility of recycling concrete aggregate into the production of new concrete to replace natural aggregates. As part of these studies a Bachelor thesis was commissioned from Ms. Sara Maukonen from XAMK University of Applied Sciences[3]. The thesis was conducted between February and August 2022.

National market conditions

Finland differs from Denmark and most Central European countries, having an abundance of natural aggregate resources. The market price of natural gravel or rock gravel in Finland is low because of good availability of high-quality granite rock and natural gravel in esker formations in Finland. There is an abundance of such resources in the Mikkeli region. The transport distances of sand and gravel is short on average.

The consumption of natural aggregates is high in Finland because of the vast geographical area, long distances and the demanding winter conditions that burden the maintenance of roads. The per capita consumption of these resources was 15,5 tons. The total consumption was about 85 million tons in 2013. About two thirds of the consumption is crushed from rock,

[1] Valtioneuvoston asetus eräiden jätteiden hyödyntämisestä maarakentamisessa 843/2017 (Decree on utilization of selected wastes in earthworks, decree 843/2017).

[2] Pekka Kammonen, infrastructure director, Mikkeli Municipality. e-mail 16.8.2022

[3] Sara Maukonen, THE USE OF CONCRETE AGGREGATE IN THE PRODUCTION OF NEW CONCRETE bachelor’s thesis Environmental Engineering 2022. South-East Finland University of Applied Sciences (XAMK).

the remaining third comes from eskers or the sea bottom. New roads are designed to utilize the rock formations along the road line.

Eskers and rock formations are valuable landscapes and 8 % of endangered species in Finland live in these ecological niches. Natural aggregate consumption is regulated by a permitting procedure. Esker formations are protected because of their importance in groundwater formation and as biotopes.

Recycled aggregates currently cover 2-3 % of the total consumption of aggregates[4].

Using a natural resource tax to promote the use of recycled aggregates to substitute natural aggregates is proposed now and then in policy discussions[5]. This has not been politically acceptable so far, because it would mostly be paid by the taxpayers, as road construction is mostly funded with public budget.

Other national policy instruments that affect the market conditions are waste regulations and waste taxes. Waste legislation obliges actors to source separate demolition wastes and to separate contaminated wastes from non-contaminated materials. A national waste tax 70 €/t is charged if demolition waste is deposited on a landfill. Recycling has been promoted by defining the quality criteria for recycled aggregates in earthworks. Following these criteria, the need to obtain an environmental permit for such recycling is revoked.

As the newest development a government decree was issued that sets the criteria for defining the end-of-waste status for concrete waste[6]. Following these criteria, the producer of the recycled aggregate can obtain a CE-certificate. This also means that the use of recycled aggregate in the production of new concrete is possible without obtaining an environmental permit for this recycling.

There are still obstacles for large scale use of recycled aggregates in concrete production. Another challenge for higher utilisation of concrete aggregate is that currently the standard SFS-EN 206 (2014) recommends that a maximum of 50 % of the total aggregate should be replaced by RCA in the lowest exposure class X0. In the rest of the classes, the recommended proportions get progressively smaller. The standard should ideally be updated to accept the use of RCA with a 100 % replacement ratio as has been done in Denmark. In the Finnish standards, there is no provision for utilizing the fine fractions of crushed concrete. [7]

[4] https://www.ymparisto.fi/fi-FI/Kartat_ja_tilastot/Ympariston_tilan_indikaattorit/Luonnonvarat/Kallion_murskaaminen_korvaa_soranottoa(27946)

[5] Parikka, Katriina, Maa-ainesvero – Ruotsin, Tanskan ja Iso-Britannian kokemuksia, Suomen ympäristö 4/2006. (Aggregate tax – experiences from Sweden, Denmark and Great Britain).

[6] Decree 466/2022.

[7] Sara Maukonen, page 39.

The business case in brief

The business case aims at promoting the upcycling option of using demolition concrete waste as the raw material for producing CE-certified recycled aggregate to be used in the production of new concrete for construction.

The value chain includes the selective demolition of concrete structures by source separation of bricks, ceramic material, and mineral wool waste from concrete. Concrete structures contaminated with asbestos, PCB, bitumen, or heavy metal paints need to be identified in the pre-demolition audit and demolished selectively to avoid mixing with non-contaminated concrete. Concrete blocks are crushed < 500 mm with demolition equipment to remove iron bars.

Instead of delivering the concrete waste to the municipal waste company, it will be delivered to a sub-contracted concrete plant for crushing and sieving. The coarse fraction (4…32 mm) will be analyzed and tested according to the quality requirements of the End-of-waste decree. The fine fraction (0…4 mm) could be used for earthworks or possibly in the future also as recycled aggregate. This is pending on updating of the national or EN standards.

Alternatively, in some cases the concrete waste could be crushed at the demolition site and stored in silos to be used in production of new concrete with mobile mixers in construction at the same site or in the close vicinity. This, however, is more challenging in terms of quality assurance and timing.

Due to the higher water absorption capacity of recycled aggregate the concrete formula needs to be adjusted by using plasticizers or other additives and tailoring the mixing program to achieve optimum plasticity, compressive strength, and resistance to damage by freezing.

Lessons learned and replication opportunities

The Bachelor thesis by Sara Maukonen demonstrated that 100 % of the coarse aggregate in the concrete mix formula can be substituted by recycled aggregate (4…32 mm). The compressive strength of the test blocks was reduced by 21…28 % when using recycled aggregate. Extra water had to be added and mixing was conducted in two stages to overcome the increased water absorption capacity of the material.

The share of fine aggregates (0…4 mm) was 43 % which is in line with Danish experiences. This fraction was not used because the Finnish concrete standard does not recognize this option. The standards should be revised to promote circular economy. Technical research is needed to assess the recycling options for this fine dust. It has a high water-absorption capacity and a considerable concentration of alkali metals and sulphates.

The concrete industry has shown much interest in the concept, but in the current situation the economic feasibility is not considered be attractive. Adopting circular criteria in tendering demolition projects is the key to changing the balance in favour of recycled aggregates. The monopoly of the municipal waste company and the low gate fees in receiving demolition waste from city owned projects constrains the business opportunities. The gate fee for receiving the waste is usually part of the recycling business concept.

Upcycling concrete waste is already a dominant concept in some Central European countries and Denmark is leading the way to the same in the Nordic countries. There is some potential for such business in Mikkeli, but the turnover potential is not more than 200 000 – 380 000 €/a. The business would be most attractive to a company that is engaged in demolition and construction services and owns a concrete plant.

The business case is applicable to any city area that generates at least 20 000 tons of concrete waste annually and has the will to promote circular procurement in demolition and construction contracts.

The business case in details

Economic aspects and benefits

Economic aspects in the value chain

In the Pankalampi demonstration case, waste fees accounted for about 22% of the demolition contract amount and about € 8 per square meter. In addition, the contractor had to pay the cost of transporting the waste. The cost of waste management was reduced by the fact that they contracted and used their own waste containers, so no rental costs were incurred.

In the Tuukkala case, waste charges accounted for 13% of the contract amount. This was somewhat lower than the typical per-centage of the initial situation (the average of the seven Mikkeli sites was 14% and the median 17%). The cost of transport by the sub-contractor was confidential information.

The waste costs would have been about double if it was not arranged in the procurement conditions that the subcontractors could use the in-house waste fees that are applied in city owned demolition projects. The pre-condition for using these in-house fees is that all wastes must be delivered to the municipal waste company.

This in-house arrangement means that circular aspects cannot be used as procurement criteria in municipal demolition tenders. Presently the contractor cannot offer the delivery of concrete waste to a earthworks project or a concrete plant for recycling. From the point of view of circular economy goals this practice needs to be revised.

From the point of view of Metsäsairila Ltd. the monopoly for waste management of city owned demolition projects means a steady flow of income. 20 000 tons of concrete waste generates 100 000 € of income with the in-house fee level and 300 000 €/a if normal list fees are used.

For the municipality this in-house practice means lower demolition contract prices due to lower waste fees. On the negative side, there is less opportunity for circular business in the municipality for the private sector. In principle the municipal waste company could process the waste into CE-certified recycled aggregate and sell it to the concrete industry. If this is the role of a municipal waste company can be challenged. The Waste Act and the Procurement Act has set a limit of 10 % of turnover to municipal waste companies for providing market-based services[8].

For the concrete industry the use of recycled aggregate would most probably not be cheaper than using natural aggregates in the current market situation. However, for a company that offers both demolition services and owns a concrete plant, this offers a major competitive advantage as it will avoid the waste fees completely. For other demolition contractors a framework agreement with a concrete plant can also be beneficial. The concrete plant could charge a gate fee for receiving concrete waste, as long as the fee is lower than the shadow price at the waste centre.

Some customers may be reluctant to use recycled concrete due to risk aversion, but other customers would consider such “green concrete” as a significant demonstration of corporate responsibility and environmental competitiveness. It can be expected that such green criteria will be adopted in public procurement also in Finland. This would mean a major competitive advantage for a concrete plant using recycled aggregates.

The concrete plant must factor in the costs of crushing, sieving and storage of the recycled aggregate or alternatively it must buy the certified aggregate from an intermediate contractor. This process is more costly than the process for natural aggregate because the fine dust from cement paste is more difficult to screen and causes lumping when moist.

The concrete company has some extra costs in using recycled aggregate because of tailoring of the mix formula, perhaps some additives and quality control costs. These are apparently not major costs after the initial testing process. Concrete plants that develop their procedures to receive recycled aggregate from demolition can easily extend this procedure to residual concrete from their own production or possibly from other regional producers.

In the long run the cost of natural aggregates is expected to rise because of conservation actions and possibly also if an environmental tax on the use of natural aggregates or “mining tax” is enacted.

Evaluation indicators for the business case

Indicator 22 in the CityLoops evaluation plan sets the goal of introducing eco-innovations: New products, service concepts and business models relating to the reuse/recycling and upcycling of the specific material flows established, leading to new business opportunities.

[8] Waste Act 145a §

Indicator 23 monitors the quantitative impacts of each eco-innovation in monetary terms.

In this Mikkeli business case the substitution of the coarse natural aggregate fraction in cement production with recycled aggregate from demolition waste is assessed.

The municipal waste company Metsäsairila Ltd. received 19536 tons of concrete waste. The concrete waste is allowed to contain brick waste or ceramic waste if it does not exceed 30 %[9]. Contaminated concrete and brick waste is source separated and not included in this figure.

When concrete waste is crushed to 0…32 mm size, the share of fine material (0…4 mm) is about 40 %[10], [11]. This cannot be used in producing new concrete because of restrictions in Finnish concrete standards[12] and technical disadvantages. The coarse fraction of recycled aggregate (4…32 mm) can be used to substitute natural aggregates. The quantity of concrete waste at Metsäsairila Ltd. could generate 11722 tons (60 %) of such material after sieving off the fine dust.

Company internet websites quote prices ranging from 20 €/m3 to 36 €/m3. Assuming a bulk density of 1400 kg/m3[13] this translates to 15…16 €/ton (VAT 0 %). Large scale users could purchase gravel with 7…8 €/ton[14]. Using a conservative estimate 8 €/ton, t*he market value of the available quantity of recycled aggregate could be about 94000 € per year.*

As a hypothetical example, Company T has a concrete factory about 50 km from Mikkeli. Their production capacity is 25000 m3 of concrete mix and 17000 m3 of concrete elements. Assuming a bulk density of 2400 kg/m3 for concrete the capacity in tons would be 60000 t/a. A typical Portland cement concrete mix consists of 27 % cement, 9 % fine aggregates, 52 % coarse aggregates and 12 % water[15].

The consumption of coarse aggregate at the plant would be 31200 tons. 38 % of this consumption could be covered with recycled aggregate, if all the waste at Metsäsairila would be available for recycling. In addition, the company could recycle its concrete production waste to increase its aggregate recycling rate even higher. Presently the company has an environmental permit for crushing 10 000 tons of concrete waste annually. This waste arises from production waste of the concrete manufacturing plants and from demolition work that another company of the same consortium is performing[16].

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[9] Valtioneuvoston asetus eräiden jätteiden hyödyntämisestä maarakentamisessa 843/2017 (Decree on utilization of selected wastes in earthworks, decree 843/2017).

[10] Sara Maukonen, THE USE OF CONCRETE AGGREGATE IN THE PRODUCTION OF NEW CONCRETE bachelor's thesis Environmental Engineering 2022. South-East Finland University of Applied Sciences (XAMK).

[11] Københavns kommune. 2020. Genanvendelse af beton. PDF document. Available at: https://www.danskindustri.dk/medlemsforeninger/foreningssites/dansk-beton/sog-publikationer/arkiv/baredygtig-beton-initiativ2/rapport-om-sydhavn-genbrugscenters-genanvendelse-af-beton-2020/ [Accessed 15 January 2022].

[12] SFS-EN 12620 (2008)

[13] Netrauta.fi/Sepeli-murske

[14] Pekka Kammonen, infrastructure director, Mikkeli Municipality, e-mail 18.8.2022

[15] Annastiina Rintala, Jouni Havukainen and Mariam Abdulkareem, Estimating the Cost-Competitiveness of Recycling-Based Geopolymer Concretes, Recycling 2021, 6, 46. https://doi.org/10.3390/recycling6030046

[16] Environmental permit 8.12.2011. Environmental board § 123/2011.

In addition to the value of the recycled aggregate the business value of recycling aggregate consists of the savings in transport and savings in waste fees. Transport of gravel costs 2-3 €/t, assuming a modest transport distance 30 km, which is typical in Mikkeli. Some digital marketplaces offer transport for 11 €/ton. The transport cost of 11700 tons of natural aggregate would be between 25000 € to 130000 €. Assuming a best case where demolition waste can be crushed and screened on-site and then used on-site for casting of new concrete structures, the saving potential would be correspondingly 25000-130000 €. However, this is generally not realistic. In most cases the concrete waste would have to be crushed centrally at the concrete plant or waste treatment facility. The transport distances would be in the same range as the transport distance for natural aggregates. *Transport savings would have to be calculated case by case, that's why these savings are not included in the evaluation indicator.*

The waste fee for concrete waste is 5 €/t if it arrives crushed with maximum 500 mm block size. The fee is 13 €/t for larger blocks of concrete[17]. These fees apply for demolition waste from city owned demolition projects. The Metsäsairila fee for other contractors than city projects are 15 €/t and 30 €/t correspondingly[18]. This latter set of fees means that the demolition contractor can save 15 €/t by delivering the waste for reuse.

at the concrete plant instead of the municipal waste company. The saving potential is 293040 €/a, if anyway the waste must be crushed < 500 mm during demolition. This saving potential is smaller if it calculated with the in-house waste fee. The in-house practice is dubious because the waste owner is no longer the municipality: the contractor is the waste owner according to the tender documents.

For the evaluation indicator estimate the market value of the concrete aggregate and the saving of waste fees can be summed up. This gives us about 386 000 € per year.

Note: the waste tax for waste deposited at a landfill is currently 70 €/ton. This tax is paid by the landfill owner and naturally it will influence the waste fee charged from the waste deliverer. For concrete waste this tax is currently avoided because all concrete waste is crushed at Metsäsairila waste center and used in the landfilling operations and road construction at site. It must be crushed below 150 mm to be excluded from tax[19]. The cost of crushing is covered with the waste fee.

Social aspects and benefits

Social aspects are not very significant in this business case. Some employment impacts can emerge from the processing of recycled aggregates in the concrete industry but that is balanced by reduced employment needs in the municipal waste company.

[17] Metsäsairila sopimushinnat 2020.
[18] https://www.metsasairila.fi/hinnat/lajittelu-ja-kierratyskeskuksen-vastaanottohinnat.html
[19] Waste Tax Act 1126/2010 § 6.

Environmental aspects and benefits

Based on a study by Kikuchi and Kuroda (2011, 123) the CO2 uptake of crushed recycled aggregate increases significantly the smaller the particle size is. The study mentions that alternately wetting and drying the aggregate also increases the CO2 uptake. Based on a survey presented in the study, the CO2 uptake of one ton of crusher-run concrete aggregate of size 0–40 mm is 11 kg[20]. This negative carbon footprint should be incorporated in LCA calculations in principle. But if the CO2 uptake is the same in landfill disposal or earthworks than in upcycling then this aspect can be disregarded.

The biggest impact on the carbon footprint of concrete lifecycle comes from the manufacturing of cement. 1,5 tons of limestone is required to produce 1 ton of cement clinker and 530 kg of CO2 is released in the process. In addition, CO2 is generated from energy consumption of 4500…5000 MJ per ton of clinker. The current footprint of the energy consumption is 300 kg CO2/ton of clinker which means a total of 830 kg CO2/ton[21]. If the quantity of cement in the concrete formula can be reduced, this would have a major impact on the footprint.

In the Copenhagen demonstration case, the cement content of the formula using recycled aggregate was 10…15 % lower than in standard C35/45 classified concrete. Fly-ash was used in both the reference concrete and the recycled concrete. However, the recycled concrete formula was optimised (optimizing details were not disclosed) to reduce cement use, but the reference concrete was not optimized to the specific case. Standard cements must be applicable for various usages, so they usually have a broader margin of safety. Anyhow, the study concluded that using recycled aggregate does not require an increase in the cement input[22].

The biggest effect on the carbon footprint in the Copenhagen demonstration was the energy required for quarrying the natural aggregate and transporting it. A 75 % saving in CO2 footprint was reported. This hardly can be applicable to Finland where natural granite aggregates are usually available quite near the consumption site.

Ramboll has estimated that in Finland the carbon footprint of stone quarrying is 2,76 kg CO2 per ton of quarried stone[23]. Recycling a corresponding quantity of concrete waste could reduce carbon emissions with an equivalent amount of CO2, if 100 % of the waste derived aggregate could be recycled. If only the 60 % of concrete waste generates aggregate that can be recycled the emission reduction potential in the Mikkeli case would be 32 t CO2 per year.

The crushing of concrete waste is estimated to have a zero impact, because crushing is anyway required as part of the demolition and waste management option. The carbon footprint of sieving is not known, but it is roughly the same for natural and recycled aggregate. However,

[20] Kikuchi, T., Kuroda, Y. 2011. Carbon Dioxide Uptake in Demolished and Crushed Concrete. Journal of Advanced Concrete Technology, 9 (1), 115–124. E-journal. Available at: https://www.jstage.jst.go.jp/article/jact/9/1/9_1_115/_pdf [Accessed 6 April 2022]. Reference by Sara Maukonen 2022.

[21] https://betoni.com/tietoa-betonista/perustietopaketti/betoni-rakennusmateriaalina/sementti-seosaineiden-kaytto/

[22] Københavns Kommune, Genanvendelse af beton Erfaringer fra nedrivning af skorsten, HOFOR Amagerværket, og genanvendelse af knust beton som tilslag i ny beton til opførelse af Sydhavn Genbrugscenter i Valby. Rapport 2020. Lauritzen Advising & Pelocon.

[23] Rambøll 2019

the recycled aggregate cannot be properly sieved if it very wet or frozen, so it will need to be stored appropriately.

Transport of aggregates with trucks generate about 0,1 kg CO2 per km per ton. This will have to be calculated case by case depending on the transport.

Indirect environmental aspects arise from the decreased pressure on using natural aggregates. The availability of easily accessible natural rock is limited in the long term. Reduction of annual consumption of natural aggregates will reduce its harmful effects on the conservation and recreational value of the potential excavation sites.

Using of recycled aggregates can in the long run reduce traffic of the transport of aggregates. In some cases, the increased crushing of concrete waste on-site can add to the noise and dust emission on neighboring residential areas.

Find more inspiration about circular market and business models in this CityLoops report: [Business Cases for Circular Construction & Demolition Projects]

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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