RECYCLING OF CONCRETE FOR SUSTAINABLE ROAD CONSTRUCTION

Why are proven methods not currently practised?

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Abstract

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This report aims to investigate why proven methods for recycling concrete waste as road construction material are not practiced in Sweden. An additional objective is to investigate how concrete is handled as a waste product and whether it would be environmentally friendly and financially beneficial to clients and contractors. Information has been extracted via interviews conducted with experts from various positions within the civil engineering industry. Additional information was obtained through literature studies and questionnaires sent and received via email.

Results which were frequently mentioned by engineering professionals included the extra expense of transporting and processing crushed concrete, parties involved in the design and construction process tend to follow traditional methods of using tried and tested virgin materials, the assumption of responsibility for structural failure due to alternative materials and general lack of knowledge surrounding crushed concrete as a construction material.

Conclusions are that crushed concrete is suitable for construction of subbases in roads and base courses of cycle/pedestrian paths. Traditionally used virgin materials are generally less expensive than crushed concrete. Existing legislation makes the use of recycled construction material difficult. Awareness and education regarding recycled concrete, as a construction material, should be increased.
SAMMANFATTNING

I den här uppsatsen undersöks varför krossad rivningsbetong och annan restbetong inte återanvänds som ballast för vägöverbyggnader, trots att studier har visat att materialet är utmärkt för ändamålet. Informationen har hämtats från rapporter som vittnar om lyckat resultat från testvägar byggda under 1990-talet i Sverige med krossad betong som ballast. Branschstandarder och krav från Trafikverket har studerats för att avgöra om det finns regler och anvisningar om huruvida krossad betong får användas i överbyggnader. Intervjuer har genomförts med projektörer, byggentreprenörer, beställare och instanser som tar emot återvunnen betong för att undersöka vem som beslutar vilket material som ska användas i en vägkonstruktion och vilka faktorer som behöver tas hänsyn till.

Problem som nämndes av alla parter var kostnaden som uppkommer med extra transport från och till rivningsplats, samt bearbetning av materialet för att framställa en användbar produkt. Projektörer och entreprenörer är obekanta med materialet och arbetar helst med traditionella material som de vet fungerar såsom jungfruligt krossat berg. Att använda ett alternativt material innebär en risk, såvida man inte kan hänvisa till en godkänd standardiserad testprocedure som visar att materialet är godkänt enligt regler och krav. Risken innebär ekonomiskt ansvar om vägen skulle behöva repareras eller byggas om på grund av otillräcklig kvalitet på det använda materialet, de intervjuade ansåg ingen är villig att ta denna risk. Från intervjuerna har det framgått att det finns en generell kunskapsbrist angående krossad betong eftersom forskning har visat på dess lämplighet som ballastmaterial i vägkonstruktioner. Det finns även utgiven kravdokument från Trafikverket som reglerar hur betong får användas i vägar av kategori A, det vill säga Trafikverksstandard.


Nyckelord: krossad betong, återanvändning, vägar, ballast, krav, AMA.
Keywords: crushed concrete, recycling, roads, aggregate, specifications, AMA.
FOREWORD

This degree thesis is written for the Department of Engineering Sciences, Construction Engineering at Uppsala University. The report was written at Tyrens Stockholm, in the road design department, with the support of Camilla Engel as mentor. The writing process was supervised at Uppsala University by Nico Van Dijk.

We would like to mention a special thanks to Camilla Engel for giving her time to guiding us through a highly complex industry, to Nico van Dijk for regularly meeting with us and providing constructive criticism and to Åsa Lindgren for helping us understand the often-confusing technical specifications of Trafikverket.

To all who welcomed us into their offices and interrupted their daily schedules to answer our questions, thank you! The information and insight gained has been invaluable for this report. They are; Åsa Lindgren, Johan Ullberg, Jonas Gustafsson, Magnus Ljungman, Martin Andersson, Richard Jorgensen, Patrik Wivstad, Andreas Åhlén, Erik Rydaker, Sven Brodin and Ulf Eliasson. Additionally, to those employees at recycling centres who answered our questionnaires, the information is much appreciated.

The report was worked on as a team project and both students contributed to all chapters. However, individual chapters were divided between us, for one person to focus on. Once a section was written, the other student would review the work and put forward suggestions for improvement. Below is a description of how the workload was divided.

Shaun Tolsma
1. Introduction, Background, Composition of a road, Natural resources, Concrete waste, Material quality
2.1 Literature study - explanation of the literature study along with the weaknesses and how the method can be improved. Research into previous test constructions documented by Boverket
2.2 Interviews - explanation, weaknesses and suggested improvements
2.3 Questionnaires - explanation
3.2 Questionnaires - writing up and summarising the answers received by recycling centres
3.3 Interviews - summarising the interviews of Eliasson, Brodin, Andersson, Wivstad and Åhlén
4. Analysis and discussion - this section was written together, with the exception of information regarding AMA, which Ingrid took charge of
5. Conclusion - discussed and written together

Ingrid Torfgård
1.1.5 Previous research and test constructions
2.1 Literature study - explanation of AMA
2.2 Interviews - compilation of bullet point questions for interviews
2.3 Questionnaires - compilation of questionnaires along with email and telephone communication with recycling centres
3.1 AMA Infrastructure - the majority of research into AMA was conducted by Ingrid
3.3 Interviews - summarising the interviews of Jörgensen, Gustafsson, Ljungman, Rydåker, Lindgren and Ullberg.
4. Analysis and discussion - this section was written together, with the exception of information regarding AMA, which Ingrid took charge of
5. Conclusion - discussed and written together

Uppsala, May 2018

Shaun Tolsma
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Appendix 1
1. INTRODUCTION

As the concern for global climate change increases, so do the efforts to conserve finite, natural resources. The construction of roads and highways is a process which consumes large amounts of material taken from the earth. Each layer of a road consists of a specific grade of aggregate. These crushed rocks are mined from quarries and transported to construction sites in large trucks.

The production of concrete also requires the use of such resources. A basic mixture of concrete consists of sand, aggregate, cement and water. The production of portland cement requires various natural resources, such as clay, shale, iron ore and limestone (Svensk betong 2018). Crushed concrete is generated from the demolition of houses, factories, bridges, hospitals etc. Another source of crushed concrete is unused or leftover concrete from casting on site and from production of prefab elements. Concrete waste is either discarded in landfill sites, used as fill material, recycled as aggregate for the production of more concrete or occasionally used in roads (Svensk Betong 2012).

Despite decades of research and attempts in Sweden to reuse and recycle various waste products, road materials and minerals, the results have been disappointing in terms of implementation. This has much to do with Sweden’s access to high quality natural gravel and bedrock in many parts of the country. Alternative materials have, therefore, not been able to compete economically with conventional aggregate. Many European countries have been using alternative materials for various construction purposes. An important reason for the extensive use of such materials in other countries is their lack of natural resources, such as gravel and rock. For example, in the Netherlands, construction and demolition waste is used as an additive in aggregate material.

1.1 Purpose

Specifications already exist regarding the use of crushed concrete in unbound layers. However, the practise is not commonly applied. Therefore, the purpose of this thesis is to investigate why the use of concrete waste in the construction of roads is not common practice, how concrete is handled as a waste product, whether it would be environmentally friendly and financially beneficial to clients and contractors. Additionally, the legal regulations and industry specifications are investigated, in order to further understand the reasoning behind current practices. Concrete as a material fulfills the requirements for
social and environmental sustainability which constitutes two of the three sustainability pillars. Economic sustainability is the third and final pillar (Figure 1.1) needed to justify the adoption of this construction method.

![The Concept of Sustainable Development](image)

**Figure 1.1** Sustainable development aims to balance three elements: economic, environmental, and social. By MIT OpenCourseWare.

### 1.2 Background

Multiple factors need to be taken into consideration when designing a road and deciding which materials to use. The standard methods involve the use of natural aggregate, cement, bitumen and water. This thesis investigates the possibility of subsidising natural aggregate with crushed concrete. The objective is not to eliminate the use of natural resources entirely. Therefore, the processes and requirements of natural aggregates in road construction are described below, along with those of crushed concrete.
1.2.1 Composition of a road

The composition of roads varies depending on the amount and type of expected traffic, local ground frost and available materials. The traffic load is determined by the number of Equivalent Standard Axles, ESA. As there are many different vehicles with various loads and wheel distributions, it becomes almost impossible to take all vehicle models into account when estimating traffic loads. The ESA method is adopted in order to make traffic load calculations possible. The method involves a single axle with a predetermined load, which represents an equivalent of the expected traffic (Granhage 2007).

Surface course

The top layer is known as the surface course, which in Sweden consists predominantly of bitumen and aggregate. The bitumen surface protects the underlying layers from exposure to water and provides a suitable driving surface for vehicles (Granhage 2007).

Base course

The surface course is supported by the base course, which is made up of high grade aggregate, bound/stabilised by either cement or bitumen. Roads which are stabilised with cement are known as rigid pavements and those stabilised with bitumen are flexible pavements. In some cases a road may contain two base courses. The upper layer is stabilised, while the lower base course is not. The base course serves to distribute the load imposed onto the surface course, by traffic, into the layers below (Granhage 2007).

Subbase

The subbase consists of unstabilised crushed aggregate and serves a similar purpose to that of the base course in terms of distributing traffic loads. Subbase layers serve four main purposes, which include creating a working surface for people and machinery during construction, protection against ground frost, drainage and bearing capacity. As the subbase is at a lower level, it is not exposed to as high a load compared to the base course. Therefore, the quality of the material need not be as high (Granhage 2007).

Protective layer/Subgrade

If the material of the roadbed consists of fine granules, there is a chance that it will mix with the material of the subbase above. This can lead to deformation in the road. In order to prevent this from happening a protective layer is placed between the roadbed and the subbase. The protective layer is either a geotextile
or an additional layer of aggregate of similar quality to that of the subbase (Granhage 2007).

**Roadbed**
The roadbed is often in-situ material, compacted to the required density. In cases where the existing material is unsatisfactory, more suitable material can be brought in to strengthen the roadbed (Granhage 2007).

### 1.2.2 Natural resources

Aggregate used in the construction of Swedish roads is mostly mined from the earth. Natural resources which are predominantly used include moraine, gravel and crushed rock. Gravel is classed as a finite resource, therefore high tax has been placed on the price of gravel in order to make crushed rock a more attractive alternative. Gravel is considered to have a particle size between 2 mm and 60 mm. Anything smaller is classed as sand and larger particles are classed as stone (Granhage 2007).

### 1.2.3 Concrete waste

Crushed concrete can be obtained from various sources and is divided into two categories namely, residual concrete and demolition concrete.

Residual concrete is made up of material left over from casting on site and from the production of prefabricated concrete elements, such as walls and floors. This kind of crushed concrete is considered to be clean and free from debris. It can, therefore, be used as filling material in earth works or as aggregate in the production of more concrete.

Demolition concrete is gathered from the tearing down of concrete structures. During the demolition process the concrete is mixed with other natural and artificial substances which are undesirable. The debris must be sorted from the crushed concrete before it can be used elsewhere. Demolition concrete is often used as filling material (Svensk betong 2012).

The European Commission’s Circular Economy Package includes targets of recycling 65 % of municipal waste and to reduce landfill of municipal waste to 10 % by 2030. According to the EU Commission, potential secondary material is lost due to the lack of recycling and overuse of landfill. The European Union
generated approximately 2.5 billion tons of waste in 2013. Of that waste, 1.6 billion tons was disposed of and lost as potentially usable material. It is believed that approximately 600 million tons of that waste could be used as secondary material (EU Commission 2015).

1.2.4 Material quality

Aggregates are categorised according to the quality of the material. Quality is determined by the aggregates grading (otherwise known as particle size distribution), bearing capacity, particle shape and density. The highest quality materials, in road layers, lie closest to the surface. As quality increases, so does the cost. Surface materials are required to be of higher quality as they are exposed to the greatest forces of pressure. The weight of a vehicle is supported by the tyres which distribute the load directly onto the surface course. The force is then spread throughout the lower layers, reducing the pressure, thereby allowing for lower quality material (Grönholm 1999).

Crushed concrete is required to be classified according to its technical properties. The crushed concrete is classed according to the original bearing capacity, age and ability to hydrate. The presence of other materials and debris, within the crushed concrete, is also considered (Vägverket 2004). Requirements for aggregate used in road construction are much higher than for aggregate used in concrete. If crushed concrete is to be used as aggregate in road construction it must be processed accordingly, in order to meet the required standards (Granhage 2007).

An aggregate is considered to be acceptable for road construction if it is well graded, has a rough particle shape and can withstand heavy loads. A good grade is a batch of aggregate which includes granules of various sizes. Variation in size allows for as many voids as possible to be filled. If voids are present after completion of construction, traffic will compress the material further and deformation will occur. Particle shape plays an important role in terms of individual stones locking against each other. Particles with smooth edges will roll and grind against one another when exposed to compaction and pressure from traffic. Therefore, a rough particle surface is desirable (Grönholm 1999).
1.2.5 Previous research and test constructions

Boverket’s material study, “Betong i vägar” by Grönholm (1999), indicates that crushed concrete has been used in Sweden in the construction of roads. Examples include road 109 outside of Helsingborg and road 597 outside of Luleå which contain experimental stretches. Crushed concrete was taken from demolished houses in Boden. The crushed concrete was able to reach the necessary quality specifications for use in the subbase. Various properties of the crushed concrete were examined, including compression resistance, frost resistance, water absorption, organic material and presence of heavy metals (Grönholm 1999). The test constructions were conducted according to technical specifications, at that time, provided by Trafikverket, VÅG 94.

In 2001 tests were conducted on an experimental road in Gothenburg. 100 m of the subbase consisted of crushed concrete. A reference section of 100 m was constructed with crushed rock. The results showed a much higher increase in stiffness in the concrete section than in the rock section, which implies that the lifespan of a road with crushed concrete increases with 20% (Carlsson 2001). At least five other tests using crushed concrete for pavement construction were performed in Sweden during the 1990s with good results (Ydrevik 2000).

Technical specifications regarding concrete were published in 1999 (Ydrevik 1999) based on Swedish and international experiences from laboratories and field tests with crushed concrete. This reference guide concludes that consolidated crushed concrete has self-binding properties, which through time increases the stiffness and stability in the material substantially. A threefold increase of stiffness within six months after consolidation/packing is not uncommon. The ability to self-bind makes concrete, in certain circumstances, a better choice of material than crushed stone or gravel. Such examples are roads with a high traffic load, bus stops, cross roads etc., where concrete, which has a higher E-module, is used for pavement structure. This can prevent tracks and cracks in the surface course. However, at a very high stress concrete has a tendency to degrade, therefore crushed concrete is not recommended for the base course where the highest stress occurs. Another reason for not using concrete in the base course is the risk of salt water penetration from the surface which affects the frost resistance in a negative way. Swedish roads are normally salted in winter to melt snow and increase traction. For bicycle and pedestrian roads there is no problem to use crushed concrete for both subbases and base courses since the traffic load is relatively low and these roads are seldom salted (Ydrevik 1999).
2. METHOD

The issues raised in this thesis are of a qualitative nature, requiring explanations to mostly open-ended questions. Therefore, the methods used to extract the necessary information include conversations with experts in the construction industry, answers received via questionnaires and a study of reports and compendia from concrete, highway, consulting and construction organisations.

2.1 Literature study

Various reports and literature were received from Robert Karlsson and Åsa Lindgren of Trafikverket, while others were recommended by Camilla Engel of Tyrens. Additionally, reports and compendia were found via internet searches. Books were loaned from campus libraries. Reference lists from reports led to additional reading material.

A disadvantage in the literature study is that the majority of material was printed during the 1990s. While modern literature can be found regarding road construction and recycling of concrete waste, no new research has been performed (to our knowledge) in using crushed concrete in Swedish roads. Technical specifications for crushed concrete in roads was printed in 2004 by Vägverket, which no longer exists. The organisation was replaced by Trafikverket in 2010. The latest technical specifications for alternative materials for road constructions was published by Trafikverket in 2014, “Alternativa material för vägkonstruktioner”. This document has been a major source of information for this thesis.

Included in the literature study is the inspection of AMA (Allmän Material- och Arbetsbeskrivning) specifications regarding the use of crushed concrete in pavement construction. AMA is a Swedish system containing descriptions of operations and materials, developed by the industry organisations. AMA is considered to be part of the standard operating procedure and is therefore commonly used. AMA is divided into different parts, for example AMA Hus (valid for housing) and AMA Anläggning (valid for infrastructure). AMA-infrastructure contains specifications regarding the type and quality of material which is permitted for use in the construction of roads in Sweden. The specifications also divide roads into their respective categories, depending on their positioning, speed limit and purpose.
2.2 Interviews

The objective of the interviews was to determine the process of handling crushed concrete and which parties were responsible for each step. Names and contact information were obtained through the mentor, acquaintances working in the civil engineering industry, interviewees and internet searches. Contact was made predominantly by telephone, in order to eliminate waiting for email responses. A brief outline of the thesis and questions to be asked were explained to the contact person. This allowed for him/her to assess whether or not they possessed the knowledge and experience relevant to the thesis. Dates and times were arranged for an interview in cases where the employee felt that he/she could be of assistance. If not, alternative contact information was usually received and the process would be repeated.

A summary of required information was drafted in order to establish questions which could yield relevant answers. Bullet point lists were written for each sector, namely construction sector, consulting, recycling and client. The list of questions would be altered slightly in order to focus on the specific company and employee, as each organisation tends to operate in different ways and each employee specialises in his/her specific field. Interviews took place in the offices of experts concerned, if they were based in either Uppsala or Stockholm. In cases where personnel were based further from Uppsala, Skype interviews were scheduled.

2.3 Questionnaires

In cases where employees lacked time for a personal interview or simple, short questions needed to be answered, questionnaires were drafted and emailed to the respective employees. All the waste management companies were first contacted by telephone in order to establish which employee had the necessary knowledge regarding crushed concrete. Questionnaires were emailed to these individuals, as they contained direct questions which were unlikely to be misinterpreted.
3. RESULTS

3.1 Literature - AMA Infrastructure

AMA is a Swedish system containing descriptions of operations and materials, developed by the industry organisations. Below is a short description of some principal features, in order to understand how AMA works and how it is composed. For AMA to be valid in the production process it must be stated in the construction contract. It is commonly used and considered to be the standard procedure, sometimes together with other specifications. Since the codes and documents which AMA refers to are Trafikverket’s specifications, this chapter could be placed under “background”, but all the interviewees, except those at Trafikverket, were unaware of the existing specifications for crushed concrete, which proves the general lack of knowledge around this material. The information that could be extracted from AMA and “Alternativa material för vägkonstruktioner” has therefore been placed under “results”.

3.1.1 Categories of road according to AMA

In Sweden, roads are classified in three categories; A, B and C. Category A corresponds to the demands that are required by Trafikverket, regarding the technical specifications and application of statistical control methods of the final product. Category A is applicable when Trafikverket’s specifications are required and also when there are higher requirements of the final surface quality etc. For example, at a reference speed of 70 km/h or higher.

Category B has been adapted to the requirements that are usually valid when roads, parking lots and so forth are constructed within an urban area. The technical difference, compared to category A, is that the statistical level control and control of the bearing strength of the formation is not required. Specifications of paved surfaces and testing of pavement, for category B, are lower than category A.

Category C is intended for foot roads, park roads and cycle paths. Additionally, for smaller roads which service rural areas. The demands are low and are, in essence, determined by the designer (RA Anläggning 17).
3.1.2 AMA and recycled concrete

The AMA codes for subgrades category A (DCB.11) and subbases category A (DCB.211) contain information regarding which materials can be used for these layers. Crushed concrete is an alternative material included in the text and therefore an approved material. The specifications for roads of category A are written by Trafikverket, since they are the main client in terms of high quality roads. Their original specifications can be found in several different documents on their website. AMA also refers to these documents. Regarding crushed concrete, mostly one document is referred to, “Alternativa material för vägkonstruktioner” written by Trafikverket (2014). This implies that if crushed concrete is chosen as a material, then there is no need to create a new code, as the existing code is valid. This is the case for roads of category A. Regarding category B and C on the other hand, there is no information at all concerning crushed concrete, which implies that conventional materials are prescribed by AMA. The industry organisation has not chosen to bring in crushed concrete as a potential material for category B and C. However, using AMA does not mean that all specifications are written in stone. The codes can be altered by adding information to the working drawings and specifications.

The technical specifications for using crushed concrete in pavement structures, according to Trafikverket’s standards, can be found in Alternativa material för vägkonstruktioner (Trafikverket 2014). There are two complementary documents: TRVK Alternativa material, which contains technical requirements used in the design phase and TRVR Alternativa material which contains technical guidelines. Many of the requirements are the same as for crushed rock. AMA is difficult to understand in terms of crushed concrete, since there are many references to “Alternativa material för vägkonstruktioner” which in turn refers to different Swedish or European Standards. Hence, an appendix was made with the assembled information from these documents, step by step, in order to easier understand which specifications must be fulfilled for concrete under the relevant conditions (appendix 1).

As mentioned above, not all specifications are the same for crushed concrete, compared with crushed rock. For example, crushed rock must be tested regarding content of organic material, while for residual concrete this is of no risk. Demolition concrete must on the other hand be tested for contamination of other construction materials and debris such as wood, plastic, insulation etc. The batch is then allocated to a class according to Table 3.1 (which also is presented in appendix 1, Figure 4, Tabell 3.1-1). Class 1 has the lowest content of debris and class 4 has the highest.
Table 3.1 Purity classification of crushed concrete. By Trafikverket.

Re stands for concrete, concrete products and cement. The number shows the lowest required percentage of this material. Rcu stands for a combination of Rc and unbound aggregate like stone and other hydraulically bound aggregate. FL stands for liquid materials (lightweight materials) and the number shows the maximum allowed amount (cm³/kg). X stands for other materials like soil, wood, plastic and metals. The number stands for maximum allowed weight percent of these materials. For example, class 3 must contain at least 70% concrete, concrete products or cement. The amount of concrete, concrete products and cement together with unbound materials like stone and other hydraulically bound materials must be 90% or more. Liquid (lightweight) materials can extend to 5% and only 1% for plastic, wood etc is allowed (SS-EN 13242).

Additionally, the testing of concrete is distinguished by the determination of bearing capacity. Here, the concrete can be divided into four classes (Table 3.2) regarding their original bearing capacity, or if that is unknown a micro-Deval test can be made. Crushed rock is usually tested with a ball-mill value, which is a test similar to micro-Deval.
Crushed concrete from demolition sites can contain hazardous substances like asbestos, mercury, PCB (polychlorinated biphenyls), PAH (polycyclic aromatic hydrocarbons), CFC (fluoride carbonates) from joint sealants, plastic foam, etc. A test must be performed to confirm that the material is not contaminated (Ydrevik 1999, TRVK Alternativa material 2013). This is a relatively simple test to perform.

### 3.2. Questionnaires

Recycling centres in and around Uppsala and Stockholm, including one recycling centre in Gävle and one in Västerås, were contacted for information. Altogether, 11 recycling centres answered the questionnaires. The main questions asked were of the type:

- How much concrete do you receive every year?
- Do you perform any tests on the concrete?
- What happens with the concrete once in your possession?

Recycling centres are contracted by demolition and construction firms to receive and handle building waste, including concrete. A construction firm will often need to demolish a structure before commencing a project. In which case, the construction firm could act as its own demolition service and client to the recycling centre.
The majority of concrete waste which enters recycling centres comes in the form of demolition concrete. A smaller amount comes from excess, unhardened concrete and a minority is received from prefab factories. The amounts of concrete waste received by a recycling centre ranges anywhere between 2000 and 50 000 tons per year. Altogether they receive around 120 000 tons per year. The amount depends on the capacity of the plant, its location and local construction and demolition activity that year.

One of the contacted recycling centres states that they will cast blocks with the unhardened concrete which they receive. The blocks are then crushed into aggregate. Excess, unhardened concrete can also be recycled internally for the construction of paved surfaces and roads. The majority of recycling centres crush and sort concrete using their own plant. Concrete which is received, crushed and sorted is either used internally as fill material for construction, sold to construction firms or dumped in landfill, if contaminated. The smaller plants use the received concrete for landfill sites or as construction material at their own plant without crushing it.

None of the recycling centres perform durability analysis in order to classify the concrete into Trafikverket’s four categories. However, they make sure the concrete is pure enough to sell or use internally. One recycling centre sends concrete waste for durability analysis in order to use the material for a new product used in pavement surfaces (see paragraph below). Most of the recycling centres state that the concrete has not been used for purposes where it needs to be classified regarding bearing capacity since there is no demand from contractors. However, one of the recycling centres is in the process of developing a tested product which can be sold to clients.

Those recycling centres which also sell crushed concrete estimate that 70-100 % of it could be sold. The amount varies depending on the current demand. One of the recycling centres mixes crushed concrete with asphalt and crushed rock in order to create a product which they call ÁV-mix 0-63. The product is sold and used in paved surfaces such as roads and parking lots. The other recycling centres sell the concrete for purposes where there is no need for classification of bearing capacity, such as forest roads, temporary construction roads, solid surfaces and filling material. However, the majority of the received concrete seems to go to internal use for the construction of service roads within the recycling centre.
One recycling centre crushed concrete into smaller fractions for some time and attempted to sell it as an alternative to crushed rock, but the low price of virgin materials makes it difficult for recycled material to be an economically attractive alternative.

### 3.3. Interviews

To investigate how the different partners in the construction industry operate when it comes to using crushed concrete, instead of commonly used materials, interviews were conducted with recycling centres, contractors, consultants and clients.

#### 3.3.1. Recycling centres

Interviews were performed with Ulf Eliasson, local manager at Uppsala bergtäkt, Svevia and Richard Jörgensen, marketing director at NCC Recycling. Svevia bergtäkt is a quarry outside of Uppsala which sells virgin material, such as crushed rock, but also receive waste material. NCC Recycling recycles waste from the construction industry and operates in the Nordic countries. The main questions asked were of the type:

- How much concrete do you receive annually?
- What happens with the concrete at your plant?
- Do you perform any tests on the concrete, such as purity or micro-Deval?

According to Ulf Eliasson, 5000 to 10 000 tons of concrete waste are received per year. Svevia does not sell the concrete to external clients. Instead, they use the concrete in the construction of their own roads in and around the quarry. Richard Jörgensen, states that NCC’s quarries and recycling centres in the Nordic countries receive between 10 000 and hundreds of tons of concrete waste per year, it depends on how one counts. Jörgensen adds that crushed concrete is used internally or sold externally.

Disposal is charged at approximately 500 kr/ton, according to Jörgensen. Concrete has a density of approximately 2300 kg/m³, making small amounts relatively expensive. Eliasson adds that recycling of concrete is more desirable, compared to disposal at landfill sites, due to the high costs of disposal of concrete waste.
Jörgensen explains that not all concrete waste produced by NCC is delivered to their recycling centre. Transport is such a major factor, in terms of economy, that if the source is located further away, a cheaper method of disposal will be considered in order to reduce transportation expenses. Jörgensen adds that once concrete is removed from the demolition site, it is immediately classed as waste and must be processed in order to return to acceptable construction material. Whereas, if the concrete remains at the demolition site and is used there, it is never classed as waste and can be used directly as construction material. However, tests for impurities such as heavy metals and PCB must be performed.

Eliasson explains that if crushed concrete is sold externally, then steel reinforcing needs to be removed, using specialised equipment and the concrete needs to be transported and sorted. These processes all cause the cost of the final product to be significantly higher than that of crushed rock. Eliasson adds that for a batch of crushed concrete to be worth processing, it would need to be as large as 20 000 tons. Jörgensen explained that NCC crushes concrete at a rate of 36 kr/ton. Prior to crushing, the concrete must be clipped with demolition shears in order to remove steel reinforcing. At a large quarry it costs around 30 kr/ton to produce crushed rock, including blasting and surface clearing. The cost is lower since the volumes are much larger and the plant is permanently established. To crush concrete a mobile crusher is needed, which requires escort vehicles. Surface area is also required for crushing and storing the concrete.

According to Jörgensen, NCC Recycling crushes and sorts concrete waste, using their own equipment at their recycling facilities. Additionally, environmental assessments are performed on the concrete according to “byggproduktionsdirektivet”, in order to determine whether or not it contains harmful chemicals and heavy metals. “Byggproduktionsdirektivet” is an EU directive which is handled by Boverket. Jörgensen explains that sealants around doors and windows are often contaminated with PCB, which is considered to be a health hazard. Jörgensen adds that steel reinforcing is removed before the concrete is mixed with virgin material (crushed rock) to form a marketable product. The product is sold to companies which use it as filling material for paved surfaces, temporary construction roads etc. The material requirements are relatively low for these purposes.
The concrete alone is not prepared for use in the construction of pavement, explains Jörgensen. Trafikverket requires that crushed concrete be classed, according to compression strength, into four categories. Such a sorting process would entail further testing, be time consuming, labour intensive and therefore, expensive. Jörgensen also states that it is a problem that demolition concrete is classed as a waste material. This implies that if the contractor wants to use it for construction work, they must have a permit from the regulatory agency to use a waste product. Obtaining the permit is not necessarily difficult, but it is time consuming and extra administration for the contractor. Jörgensen adds that he has experience with this issue and has had conversations with Naturvårdsverket who regulate this legislation. He explains that it is complicated regarding all the different legislation. For waste material, the landfill and waste legislation apply and if the material is to be sold then “byggproduktionsdirektivet” applies. Additionally, there are rules about how long the material is allowed to be stored, and when the concrete is crushed you must have a permit for mechanical processing of waste material if it is executed a place other than the demolition site. The rules and regulations make for a complicated procedure and can scare people off.

Svevia bergtäkt does not possess the necessary equipment used for crushing and sorting. Eliasson explains that the concrete waste is used in quarry roads in the condition which it arrives, if the source is known.

Eliasson states that there is no demand, from the Swedish construction industry, for recycled concrete. He goes on to explain that in other countries, such as the Netherlands and Germany, it is a legal requirement to use a certain percentage of recycled material in construction processes. He believes that this is partly due to the fact that Sweden has large amounts of naturally occurring rock available, while the Netherlands and Germany are forced to either import rock or recycle existing materials. Eliasson is of the opinion that the Swedish construction authorities, such as Trafikverket, would need to apply new material specifications, in order to make recycled concrete economically beneficial for clients and contractors.

Jörgensen is of the opinion that Trafikverket is not up to date and that it is very difficult to bring out a product that corresponds to their technical specifications. Jörgensen reckons that it should be made easier for contractors to use recycled concrete by adjusting the technical specifications. Currently, the sorting and testing requirements are too expensive and time consuming for contractors to consider using crushed concrete. Jörgensen suggests that
Trafikverket, Naturvårdsverket and the larger contracting firms could come together and agree on a set of regulations that allow, for example 10%, crushed concrete mixed with virgin materials, given that the concrete is not contaminated. Additionally, compression strength tests could be performed on the final product.

3.3.2. Contractors

Two representatives from contracting firms were interviewed: Jonas Gustafsson, project manager at NCC Uppsala and Magnus Ljungman, project manager at Skanska Stockholm. The main questions were of the type:

- Who is responsible for choosing materials in road projects?
- Do you have any experience of a road project where crushed concrete was used?
- Which advantages and disadvantages exist when using crushed concrete instead of commonly used materials?
- Why do you think concrete is not used, even though it has been proven as a good material?

Regarding who is responsible for choosing material for the road, Gustafsson states that the consultant decides on the material. According to ABK 09 the consultant is responsible for the integrity of the design. If the contractor is responsible for the design process, then they are able to influence certain decisions. Gustafsson adds that the consultant generally does not want to deviate from standard materials, mentioned in AMA, as they will then take on the risk of responsibility for any failures in the construction. Magnus Ljungman of Skanska, site agent, states that Trafikverket has technical specifications which refer to AMA. The consultant will decide on material quality according to Trafikverket’s specifications. However, according to AMA and information received from consultants, this is not always the case. The contractor may have the opportunity to choose materials, given that the material meets the requirements stated in AMA and other relevant specifications.

When it comes to transportation of material to a road project, it is important that the distance is the shortest possible. Transportation of crushed concrete from a demolition site to the construction site can be costly, depending on the distances involved, according to Gustafsson. If a structure is being demolished in close proximity to the construction site, then the use of crushed concrete will be considered. A temporary sorting station can be erected at the construction
site in order to eliminate transportation to and from a recycling centre. Transportation of material is such an influencing economic factor that if the contractor has a quarry near the construction site then they will most likely be awarded the tender, due to the reduced transportation costs, explains Gustafsson.

Gustafsson states that crushed rock is required to go through certain test procedures before it can be approved for construction in specific layers of a road. Material companies have systems in place for the various materials. Regarding concrete, the source, age, strength and environmental hazards all need to be assessed before considering it as construction material. Crushed concrete would also need to be tested, in order to be sure of equal quality. Gustafsson speculates that the crushed concrete may be of lower quality, in which case the relevant layer may have to be designed thicker in order to compensate. It is accepted that crushed rock can withstand the forces of heavy construction vehicles, but with concrete there is a risk that the particles may be crushed, which will alter the particle distribution in the layer, according to Gustafsson.

Gustafsson added that at NCC crushed concrete is occasionally used in the protection layer and as fill material for parking lots, but seldom in roads as the requirements are too strict. Parking lots are exposed to less pressure from heavy traffic, therefore standards are lower. The normal construction contracts state a five-year guarantee and if road reparations are required it can be very expensive for the contractor. Gustafsson believes that the risk is too great.

When it comes to the amount of material required to construct a subbase layer, Gustafsson speculates that it might be too large for crushed concrete. The demolition of a structure can only yield so much usable material. A subbase layer is 450 to 550 mm thick and can be many kilometers in length. Constructing a section of the layer with crushed concrete and the rest with crushed rock is undesirable, as the two materials will not mix well and will compact differently over time, causing inconsistencies in the form of the road, explains Gustafsson.

Ljungman states that he was involved in the construction of a bicycle path between Märsta and Rosersberg, where crushed concrete was used as pavement material. Sigtuna kommun was the client and had provided crushed concrete for the project and subsequently took the risk for using it. Ljungman mentions that demolition concrete is occasionally used in the creation of service roads
within a construction site. However, Ljungman does not know of any road constructions involving crushed concrete.

Gustafsson was asked if NCC would consider using concrete for reparations of damaged roads, but as they are unsure of the quality of the final product, they would not. It is safer to use tried and tested materials such as granite and gneiss.

Gustafsson states that NCC does not purchase crushed concrete for use in construction. NCC has its own recycling centre (NCC Recycling) which supplies crushed concrete when needed. NCC Recycling performs its own tests on crushed rock in order to ensure that the material fills the requirements in AMA. NCC Recycling would need large areas to accumulate enough crushed concrete over time to use in road construction, as the storage of material entails costs. Compared to crushed rock it would be much larger amounts since the rock stores are regularly refilled. For example, NCC never produces an annual consumption amount of crushed rock at one time, since the storage costs would be too high. Instead, when there are approximately three months of supply left, rock is crushed to refill supplies. Storage would bring back the issue of transporting crushed concrete between the demolition site, recycling centre and construction site, thereby raising the tender price considerably. The best way would be to transport the concrete from the demolition site directly to the place where it will be used.

Ljungman explains that because of material specifications, crushed concrete is not considered in the construction process. Ljungman mentioned the issues of obtaining the required grade of material, sufficient amounts of crushed concrete, removing steel reinforcing and the economical aspect. These are all uncertainties when testing an alternative material. Crushed rock is the safe option.

According to Gustafsson, local municipalities are unsure of how to reuse crushed concrete and therefore, more cautious. Gustafsson adds that some environmental inspectors believe that crushed concrete is not environmentally safe for reuse and should be disposed of at landfill sites. Documentation is required to prove where the demolished material will be transported and whether or not it will emit harmful chemicals into the ground and watercourse.

Gustafsson was asked if NCC would consider using crushed concrete in the construction process if there was a procedure in place which could guarantee
quality. Gustafsson believes that it would depend on the price. The cost would need to be much lower, in comparison to crushed rock, for a contractor to justify the risk of using a different material. The supply and demand must also match each other, considering the storage costs. Additionally, the client must request for crushed concrete to be used. Both contractor and client aim to save money where possible. Ljungman states that Skanska would never be awarded a tender if they quote a more expensive construction material. He adds that Trafikverket would have to request the use of crushed concrete in the project, in order for the contractor to consider it. Ljungman explains that economy is a major factor.

Ljungman believes that crushed concrete could be used in the construction of smaller projects, such as cycle and pedestrian paths. The material requirements are of a much lower standard. Ljungman adds that, in the project between Märsta and Rosersberg, the crushed concrete released cement when exposed to moisture and created a satisfactory solid layer.

3.3.3. Consultants

Two consultants were interviewed at Structor Uppsala: Patrik Wivstad and Andreas Åhlén. Another interview was conducted with Erik Rydåker at Tyréns Stockholm. The main questions were of the type:

- Do the consultants decide on material quality when designing a road?
- Is it possible for you to prescribe concrete instead of traditional rock?
- What is the reason that crushed concrete is not prescribed/used in road constructions?

According to Wivstad and Åhlén of Structor, material selection is performed according to the specifications from AMA and Trafikverket. Wivstad and Åhlén explain that the consultant’s working drawings refer to “kross”, which implies crushed rock, to avoid the use of natural gravel. In some cases the grade of material can also be specified, but this is usually left to the contractor to decide on the most economically suitable option. Erik Rydåker of Tyréns states that material selection depends on the location of the proposed road. Stockholm’s stad, for example, has its own technical specifications for various pavement types, based on the expected traffic. Rydåker explains that consultants are required to follow the specifications and that they are not often adjusted.
It is possible for the consultant to prescribe crushed concrete, according to Wivstad and Åhlén, but the client would need to be in agreement with the use of an alternative material. Rydåker echoes the sentiment that the consultant can design with crushed concrete, but not without the knowledge of the client. He states that the client must make the request for alternative material and that the risk will then lie with the client. Rydåker adds that the consultant would need evidence that the specific alternative material does fulfill the necessary technical specifications, before prescribing it in the design.

Åhlén adds that long-term maintenance needs to be taken into consideration, when deciding on material. A layer of crushed concrete, with self-binding properties, could be difficult to break through during maintenance procedures and therefore, unsuitable in the long-term. Although this may be a potential disadvantage, the advantages of having a solid concrete layer could outweigh the negative aspects.

Wivstad and Åhlén state that a client has never requested that they use an alternative material in road design. They are of the opinion that clients, who develop a whole block with both buildings and roads, are more concerned about environmental certification of buildings, rather than infrastructure and earthworks.

Habit, traditional methods and assuming responsibility for damages due to alternative materials hinder consultants from specifying crushed concrete in designs, according to Wivstad and Åhlén. They add that there could be a fear of trying new methods and that it is safer to apply tried and tested techniques. Rydåker is of the opinion that it would be easier to convince a client to apply alternative materials in a cycle path or walkway project, as the material criteria is much lower and involves lower risk.

Wivstad and Åhlén are of the opinion that large municipalities would need to be attracted to the concept of recycling concrete, in order for the practice to begin being implemented in road design. Municipalities such as Malmö and Stockholm have the budget to finance the research and construction of such a venture. Wivstad and Åhlén add that Trafikverket would need to adjust their technical specifications in order to make crushed concrete more accessible as a construction material. Adjustments to legal requirements and general awareness of the issue would also contribute to implementation, according to Wivstad and Åhlén.
3.3.4. Clients

Four persons have been interviewed: Sven Brodin, project leader at Stockholms stad, Martin Andersson, project leader at Uppsala kommun, Johan Ullberg, specialist at road technology, Trafikverket and Åsa Lindgren specialist at sustainability, Trafikverket. The main questions were of the type:

- Who is responsible for choosing materials in road projects?
- Do you have any experience of a road project where crushed concrete was used?
- Which advantages and disadvantages exist when using crushed concrete instead of commonly used materials?
- Why do you think concrete is not used, even though it has been proven as a good material?

Municipalities

According to Brodin at Stockholms stad, crushed concrete is a suitable material for construction of category B and C roads, due to the lower material quality requirements. However, Brodin believes that the majority of crushed concrete is used as fill material. He explains that this is much simpler and there is generally no problem with contamination within the concrete, with exception to demolition concrete from older houses containing chemical sealants.

Martin Andersson, project leader at Uppsalan Kommun, is not aware of any construction projects within Uppsalan Kommun where crushed concrete has been used as a material. Andersson believes that is due to the fact that crushed concrete is not produced in sufficient quantities, the construction industry follows traditional norms and crushed concrete is usually more expensive than rock.

Brodin states that the road construction projects in Stockholms stad are too large to consider crushed concrete as a material. The amount of material required can only be supplied in the form of crushed rock. Brodin adds that the Stockholm region is rich in rock. The material is not only obtained from quarries, but also from excavation sites at construction projects. Brodin gives the example of tunnel excavations, where large amounts of rock, perfectly suitable for construction are obtained. The issue of transportation, according to Brodin, needs to be taken into consideration, as it can significantly affect the cost of material. Additionally, Brodin states that using rock can be more
environmentally friendly, in terms of CO₂ emissions, due to the transport required in the processing of crushed concrete.

As project leader, Brodin states that he is responsible for the selection of material in road layers, while following AMA guidelines. Brodin explains that it is possible to use a mixture of crushed concrete and rock to create a usable aggregate. However, the blending process will raise the cost of the final product. It would be more economically beneficial to sell the crushed concrete and rock separately. Andersson states that he and a designer will decide on the materials to be used, in accordance with AMA. Andersson explains that deviations from AMA are avoided, in order to be certain of the quality of the final product.

According to Andersson, there are currently no laws or regulations which require contractors to use any specific amount of recycled material in new constructions. The only requirement is that material adheres to the technical specifications. Andersson believes that, in order for recycled materials to become a regular part of the design and construction processes, the municipality would need to adopt a policy which involves the use of recycled material. Alternatively, politicians would need to be made aware of the issue and establish a legal requirement for recycling construction waste.

*Trafikverket*

Since the interviewed persons from Trafikverket are well-grounded in the technical specifications “*Alternativa material för vägkonstruktioner*” and the test roads and other research about concrete for road constructions that were made in the 1990s, questions were also asked about what occurred after this era of positive prospects, why concrete was suddenly not considered an interesting material any longer.

Johan Ullberg is unsure of why crushed concrete did not continue to be used after the test roads in the 1990s were built. He states that the organisation purchases a road as a whole, and does not intervene in the material selection. However, the contractor is expected to follow Trafikverket’s technical specifications, which do include guidelines for alternative material. There is no reluctance from Trafikverket but they have not pushed for the use of alternative materials either, explains Ullberg. He believes that contractors prefer to use the traditional materials, as they are tried and tested. Perhaps, in the 1990s, those who executed all this research thought that concrete would be a breakthrough or that there would be greater amounts of concrete available.
Åsa Lindgren states that, at Trafikverket, the idea of using crushed concrete for the pavement structure has been around since the 1990s, and still is. However, after all the research was executed and the test roads were built, the idea was put aside. The technical specifications for crushed concrete were written to open the possibility to use crushed concrete and other alternative materials, and hence give the contractors the opportunity to choose different materials. Lindgren agrees with Ullberg and believes that contractors probably prefer to use materials to which they are accustomed.

Ullberg is not aware of any requirements, within Trafikverket, regarding the use of certain amounts of recycled material. However, Trafikverket does require that roads and railways are built in an environmentally friendly way, with regard to carbon dioxide emissions for example. Lindgren confirms that there are no specific requirements for using a certain amount of recycled concrete within their projects. There are, however, requirements for asphalt. Lindgren recounted the same problem as Jörgensen at NCC Recycling, that concrete is classed as waste, which means that a registration has to be sent to the local regulatory agency if recycled concrete will be stored. An additional registration has to be sent if the concrete will be used for construction purposes. This procedure is not necessarily complicated but it takes time, the verdict is uncertain and it becomes an extra administrative routine. This obstructs material recycling and the idea of a circular economy.

Blast furnace slag is another alternative material used for road construction, which is widely used today, according to Lindgren. She adds that this material is classed as a byproduct from an industrial process and hence never receives a waste classification. Therefore, it follows, more or less, the same rules as for regular products which are sold and bought on the market. If a similar regulation could be made for crushed concrete i.e. the concrete would be classed as a product, then the recycling procedure would be simplified. There is, however, a problem since the crushed concrete is sourced from many different places and in many different classes regarding bearing capacity, purity etc. In that case the industry must come together and agree on standardised tests and responsibility of performing these tests. If that would happen, crushed concrete could probably be sold as an eco-friendly material and be more attractive on the market, according to Lindgren. She adds that economy is the remaining problem and that there is no incentive for contractors to adopt the practice. Lindgren mentions the possibility of a legislative demand to recycle more material.
4. ANALYSIS AND DISCUSSION

The consultant designs the various layers and assigns material quality in accordance with AMA. The contractor receives the working drawings and specifications from the consultant and proceeds to order material which meets the requirements. The contractor is most likely to order traditional materials, as they are more familiar. Neither consultant nor contractor seem willing to take the risk of using an unfamiliar material. The risk of using crushed concrete - or any alternative material - is assumed by the party who recommended or requested the product.

Weaknesses observed in the interview method include how the interviewers were inexperienced, interviews conducted later in the course were conducted more efficiently with refined questions. The answers from the interviews cannot be assumed as fact, as many of the interviewees were not experts in crushed concrete and their answers were often personal opinions or assumptions. Additionally, as employees of engineering firms, it is our assumption that interviewees provided answers which defended their professional practices. In other words, the answers may have been biased. The research is concentrated to Mälardalen, but not all the recycling centres answered the questionnaires and there are probably other recycling centres that we missed. More interviews could have been performed with other contractors and other municipalities. If the research had been performed in a region with poor access to rock, such as Skåne or Gotland, the result would probably have been different.

4.1 AMA and regulations

Since AMA Anläggning does not deal with crushed concrete as an eligible material for subbases and protection layers for category B and C roads, it leaves out the option of using crushed concrete if one chooses to use AMA without adding or changing information. The default material is crushed rock and will likely be used if the client does not push for using a recycled material. It is a pity since, as mentioned before, concrete would be a very good material for pedestrian and bicycle roads. It could probably be used without performing any tests on bearing capacity. For category A roads there is an option, according to AMA, to use crushed concrete. This implies that crushed concrete is considered to be a qualified material for road construction. Gustafsson mentioned that if crushed concrete is used, there is a risk that the particles may be crushed, which will alter the particle distribution in the layer. This is true
and that is one reason why concrete is not recommended for base courses where the highest stress occurs. The specifications can be found in “Alternativa material för vägkonstruktioner” which was written to open up the possibility for the contractors to use alternative materials. However, there are many requirements which must be fulfilled and they are relatively complicated to adopt, which is potentially one reason why concrete has not become a more commonly used material.

Andersson, at Uppsala Kommun, stated that they follow AMA and try to avoid deviations in order to be certain of the quality of the final product. Since the municipalities generally build roads of category B and C, crushed concrete falls away as an option. Brodin at Stockholms stad states that they follow AMA in their projects together with their own technical handbook (which refers to AMA regarding material for subbases). This is a problem since the municipalities are unlikely to write their own technical specifications. It is much easier and less time consuming to just prescribe the existing technical specifications. This issue was pointed out during email contact with one of the authors of AMA anläggning. The author commented that it was good input for the next revision of AMA which launches this autumn (2018).

An additional problem which obstructs the usage of crushed concrete is the classification as a waste material as soon as it is transported away from the demolition site. This implies that the contractor needs a permit for storage and an additional permit for use in construction. This is time consuming and an extra administrative duty. According to Jörgensen at NCC Recycling, permission for mechanical processing is also required to crush the concrete. If concrete is not classed as a waste material there would still need to be some form of standardised quality, environmental and technical testing to ensure the concrete satisfies certain standards. Trafikverket’s existing standards are only valid for roads of category A and they are, according to Jörgensen, difficult to accommodate. These tests would, most likely, include bearing capacity (if it is unknown) and purity in conformity with Trafikverkets standards (Table 3.1, 3.2 and appendix 1). If Trafikverket, Naturvårdsverket and the large contractors came together and agreed on a set of regulations, for how crushed concrete could be used, it could set the process in motion of adopting crushed concrete for construction. Jörgensen’s suggestion of allowing 10 % concrete mixed with virgin materials is an interesting solution. This would alleviate the problem of insufficient concrete available on the market for an entire road. Brodin believed that the blending process would lead to a more costly process.
However, NCC Recycling already markets a mix of crushed concrete and crushed rock which implies that the process is profitable. If the concrete would be processed at the quarries the material could be mixed there and ready to collect for the contractors. The standard procedure is, since the quarries receive excavation material and concrete from demolition sites, for the contractors to deliver such material from the construction site and reload the truck with needed material and return to the construction site. The same procedure would be applicable for fetching crushed concrete (or a mix of concrete and rock) if it was processed at the quarries. This would reduce transportation costs for crushed concrete, thereby, allowing it to compete against virgin materials for economic preference.

4.2 Economy and transport

Relatively large amounts of concrete are needed to make it economically profitable to crush and sell. Therefore, only those quarries or recycling centres who receive enough can afford it. This is potentially one of the reasons why several interviewees stated that there is not sufficient concrete available on the market. This might be true, but on the other hand, tons of concrete “disappears” at the medium sized recycling centres for internal roads, landfill etc. A reason why concrete is not used today, according to the interviewees, is that it is only available in specific places which are located too far away to make it economically profitable, regarding transportation costs. If concrete would be gathered at a select few quarries (or recycling centres) the amount could potentially be enough to be economically viable for crushing. If these quarries are strategically positioned around a city, more construction sites will be situated within the economically supportable transportation zone.

In cases where a relatively large structure is being demolished, it can be economically beneficial to crush the concrete on site, for construction at the same site, or nearby. It is more probable that a building, bridge or any other type of concrete structure is being demolished in town than in the countryside. Therefore, it would be more beneficial to use crushed concrete in city roads, from a transportation point of view. The shorter transport distances will reduce the cost of material and benefit the environment by not emitting unnecessary exhaust fumes. However, there is limited working space in urban areas. Surface area for sorting, storage and machinery is difficult to find in a congested city, such as Stockholm. In that case, the best option would be to transport the
demolished concrete to one of the suggested, strategically positioned recycling centres.

An additional reason, mentioned by the interviewees, for not using concrete is the risk of using an unknown material. As stated by Gustafsson, the normal construction contracts state a five-year guarantee and if road reparations are required it can be very expensive for the contractor. However, if the concrete fulfills the specifications by AMA and Trafikverket there is no larger risk than using traditional materials. If reparations are required after the five-year guarantee the risk passes to the client.

It is important to see the whole picture and not prescribe crushed concrete purely for the sake of using recycled material. If the transportation distance is much greater than for crushed rock, it should not be prescribed at the expense of greenhouse gas emissions. When rock must be blasted or excavated in order to build a road, the available material should be used to minimize transportation.

### 4.3 Processing of concrete

Currently, the sorting (Trafikverket’s four classes) and testing requirements are too expensive and time consuming for contractors to consider using crushed concrete. If the concrete is gathered from various sources and the amount received is large enough to install a permanently established crusher, it would decrease the cost and be economically profitable. The space for storing large amounts of material appears to be a problem today since one must accumulate large amounts before it is possible to sell. On the other hand, crushed stone is stored in large amounts at the quarries. According to Gustafsson the stores are filled up when there is approximately a three month supply left. If this flow could be achieved with concrete it would be an economically viable alternative.

The effort involved in acquiring, sorting and transporting crushed concrete needs to yield a substantial economic reward for both the contractor and client in order to be a considerable option. While most companies do claim to take environmental issues into account in business operations, it would seem that financial incentives are a of a higher priority. Currently, it is simpler and more efficient to continue following the existing methods of road construction, along with the tried and tested materials. The higher cost for processing the concrete could be reason enough to adjust legislation or implement financial incentives for using more recycled material. Government could set pressure on both
Trafikverket and the municipalities to request roads constructed with more recycled material.

4.4 Sustainability

Using an alternative to crushed rock has a positive environmental impact in that it reduces the amount of virgin materials being mined and used in construction. In Sweden there is good access to rock, but believing that it is an infinite material is short-sighted and irresponsible. Concrete is available and it has been proven a very good material for road construction, sometimes even better than commonly used materials such as crushed rock, given that the required classes for different roads and layers are adhered to. Old habits must give way for a circular economy. Recycling concrete waste into a secondary construction material could assist in achieving the EU Commission’s targets in the Circular Economy Package by 2030.

On the other hand, concrete is currently recycled and used for purposes where there is no need for classification of bearing capacity, such as fill material, forest roads, temporary construction roads and solid surfaces. Only a small amount of the concrete ends up as landfill, mostly contaminated concrete. A considerable part of the received concrete at recycling centres seems to be used internally for construction of service roads within the recycling centre. One recycling centre mixes crushed concrete with asphalt and crushed rock in order to create a product which is sold and used in paved surfaces such as roads and parking lots. Our impression is that a large part of the concrete ends up as fill material. It is good that concrete is recycled for this purpose, but it could serve a higher purpose since the material quality is of a high standard. Other materials such as brick could fulfil this purpose.

Crushed concrete, as a construction material, fulfils the requirements for social sustainability since the experimental roads constructed in the 1990s showed an increase in lifespan with 20 % and decrease in tracks, which provides usable infrastructure for society. Regarding environmental and economic sustainability, it depends on the transportation distances, as discussed above.
5. CONCLUSION

Technical properties and requirements
Crushed concrete may be used as a construction material, given that it meets the requirements stated by AMA under “alternative materials”. Crushed concrete is best suited to the subbase of roads, but not suitable for layers above the subbase. Additionally, crushed concrete is suitable in the construction of pedestrian and cycle paths.

Economic feasibility
The methods and processes used to transform concrete waste into a construction material make crushed concrete economically unattractive to clients and contractors. In order for the construction industry to take recycling waste material into serious consideration, there will need to be a financial incentive for all involved. Alternatively, a legal requirement to use a certain percentage of recycled material.

Adjusted legal requirements
Legal framework, which classes concrete as a waste material once it leaves the demolition site, makes it complicated and time consuming for contractors to use as construction material. More lenient regulations around concrete waste could encourage contractors to recycle the material, instead of disposing of it at tips or using it as fill material. Other waste materials such as brick could fulfil this function, thereby making crushed concrete available for higher purposes.

Currently there are only specifications for category A roads. The large partners in the construction industry would need to agree on general specifications which include roads of category B and C. This could set the process in motion of adopting crushed concrete for construction. Allowing 10% concrete mixed with virgin materials is an interesting solution. This would alleviate the problem of insufficient concrete available on the market for an entire road.

Awareness and education
All partners involved in the construction process need to be made aware that crushed concrete is a suitable alternative to crushed rock. Politicians would also need to be informed of the issue, in order to adjust legal documentation, mentioned above.
5.1 Suggestions for future research

We would recommend a life cycle cost (LCC) analysis be performed on roads and bicycle paths constructed with crushed concrete. This would determine whether or not the use of crushed concrete is financially beneficial in the long term.

As the priority for clients and contractors is to maximise profit, the possibility of implementing financial incentives for the use of recycled materials would be worth investigating. Would the financial incentive be sufficient motivation to adopt alternative materials and would it be feasible?

Investigations on how to class concrete as a construction material, instead of waste, after removal from the demolition site. This may entail an environmental assessment of the concrete immediately after demolition.
References


**Figure/table register**


Appendix 1

INTRODUKTION
Krossad betong går att använda till både skyddslager och förstärkningslager för vägar av kategori A enligt AMA Anläggning. Information om hur krossad betong och andra material kan användas ingår under respektive kod, t.ex. koden för skyddslager. Detta innebär att entreprenören är fri att själv välja material för skyddslager och förstärkningslager. Som klargörs nedan behöver det utföras vissa tester på betongen innan den kan användas. AMA hänvisar till Trafikverkets dokument ”TDOK 2013:0532 – Alternativa material för vägkonstruktioner” för många av dessa krav men även till ”TDOK 2013:0530 – Obundna lager för vägkonstruktioner”. I dessa dokument hänvisas i sin tur till vissa standarder för hur egenskaper ska deklareras, liksom krossat berg eller sten också ska deklareras enligt vissa standarder. Informationen är spretig eftersom det hänvisas till olika handlingar och därför har detta dokument skapats som en hjälp för att lättare kunna överskåda kraven. I detta dokument tas endast upp krav som är specifika för krossad betong, det finns andra generella krav som ska uppfyllas vad man än väljer för material, se respektive AMA-kod för dessa. Text med grön ram är AMA-text och text med svart ram kommer från något av Trafikverkets dokument.

1. SKYDDSLAGER
AMA skriver så här om skyddslager (undre förstärkningslager):

<table>
<thead>
<tr>
<th>DCB.1</th>
<th>Undre förstärkningslager för väg, plan o d</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMA</td>
<td></td>
</tr>
<tr>
<td>MATERIAL- OCH VARUKRAV</td>
<td>Undre förstärkningslager ska utföras av materialtyp 1 eller 2 enligt tabell AMA DC/1.</td>
</tr>
</tbody>
</table>

Tabell AMA DC/1 visas i Figur 1.
<table>
<thead>
<tr>
<th>Materialtyp</th>
<th>Benämningar Berg- och jordmaterial, Kulkvamvärde</th>
<th>Halten (vikt-%) X/Y</th>
<th>Exempel</th>
<th>Tjallfarighetsklass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Finjord 0,06/63 mm</td>
<td>Ler 0,002/0,063 mm</td>
<td>Organisk jord %/63 mm</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bergtyp 1 ≤ 18</td>
<td>≤ 10</td>
<td>≤ 2</td>
<td>Glimmerfattig granit ellergnejs samt andra hårda och hållfasta bergarter såsom kvartsit, diabas, porfyr och leptom</td>
</tr>
<tr>
<td></td>
<td>Bergtyp 2 19-30</td>
<td>≤ 10</td>
<td>≤ 2</td>
<td>Glimmerrik granit ellergnejs samt andra bergarter med mättlig hållfasthet och dålig slitstyrka t.ex homogen kalksten</td>
</tr>
<tr>
<td>2</td>
<td>Block- och stenjordarter Grovkorniga jordarter</td>
<td>≤ 15</td>
<td>≤ 2</td>
<td>Block, Sten, Grus, Sand, Sandigt grus, Grusig sand, Grusmorän, Sandmorän</td>
</tr>
<tr>
<td>3A</td>
<td>Bergtyp 3 &gt; 30</td>
<td>≤ 30</td>
<td>≤ 2</td>
<td>Bergarter med höga glimmerhalter, lerskiffer, krittåken, leromvandlat berg samt inte klassificerat bergmaterial</td>
</tr>
<tr>
<td>3B</td>
<td>Blandkorniga jordarter</td>
<td>16-30</td>
<td>≤ 2</td>
<td>Lerg eller siltig sand, Lerg eller siltig grus, Lerg eller siltig sandmorän, Lerg eller siltig grusmorän, Lerg eller siltig morän</td>
</tr>
<tr>
<td>4A</td>
<td>Blandkorniga jordarter</td>
<td>31-40</td>
<td>≤ 2</td>
<td>Lerg eller siltig sand, Lerg eller siltig grus, Lerg eller siltig sandmorän, Lerg eller siltig grusmorän, Lerg eller siltig morän</td>
</tr>
<tr>
<td>4B</td>
<td>Finkorniga jordarter</td>
<td>&gt; 40</td>
<td>&gt; 40</td>
<td>≤ 2</td>
</tr>
<tr>
<td>5A</td>
<td>Finkorniga jordarter</td>
<td>&gt; 40</td>
<td>≤ 40</td>
<td>≤ 2</td>
</tr>
<tr>
<td>5B</td>
<td>Mineraljordarter med organisk halt</td>
<td>3-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6A</td>
<td>Organiska, mineraliska jordarter</td>
<td>7-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6B</td>
<td>Organiska jordarter</td>
<td>&gt; 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Restprodukter Atervunna material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lättmaterial</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figur 1. Tabell AMA DC/1
Vid kontakt med Trafikverket klargjordes att detta inte betyder att man måste använda materialtyp 1 eller 2 för skyddslager, utan att om man väljer krossat berg eller sten så ska kvalitén vara av materialtyp 1 eller 2. Under DCB.11 finns föreskrifter om man väljer att använda krossad betong.

Tabell AMA DC/1 visas i Figur 1.
Alternativa material för vägkonstruktioner, TDKO 2013:0532, avsnitt 3.3.1 visas i Figur 2.


3.3.1 Levererat material

Samtliga inköpta material med sorteringen ≤0/90 ska vara deklarerade (CE-märkta) enligt SS-EN 13242 ”Ballast för obundna och hydrauliskt bundna material till väg- och anläggningsbyggnad” med tillverkarförsäkran enligt användning utan höga säkerhetskrav (system 4) och enligt SS-EN 13285 ”Obundna överbyggnadsmaterial, Specifikation”. Samtliga material med sorteringen > 0/90 ska vara deklarerade med tillverkarförsäkran enligt AMA Anläggning, nivå 4.

3.3.1.1 Krav på material

Materialegenskaper beskrivna i avsnitt 3.3.1.1.1 till 3.3.1.1.3 ska vara deklarerade.

3.3.1.1.1 Klassificering av sammansättning på återvunnen ballast

Materialet ska uppfylla kvalitetsklass 3 enligt tabell 3.1-1.

3.3.1.1.2 Kornstorleksfördelning

Sorteringen ska deklaras och vara minst 0/16. Övre kornstorleksgräns D enligt SS-EN 13285 får inte överstiga halva lagertjockleken. Finnmaterialhalten ska deklaras enligt SS-EN 13285 och får inte överstiga kraven för kategorin UF12 (12 %).

3.3.1.1.3 Nötningsegenskaper (micro-Devalvärdet)

Nötningsegenskaperna ska deklaras enligt SS-EN 13242 och ska minst uppfylla kraven för kategorin Mg 40. Om materialet inte trafikerats av mer än enstaka tunga fordon (totalvikt över 3,5 ton) under byggskedet kan micro-Devalvärdet uppgå till 50. Kravet på nötningsegenskaper kan ersättas med krav på betongkvalitet enligt tabell 3.1-2.

Figur 2. TDOK 2013:0532, avsnitt 3.3.1

Detta betyder alltså att krossad betong med en fraktion <0/90 ska deklaras enligt SS-EN 13242 och SS-EN 13285 vilket även gäller för stenmaterial. Krossad betong med en fraktion >0/90 ska deklaras med tillverkarförsäkran enligt AMA Anläggning, nivå 4 (Figur 3) vilket innebär tillverkarförsäkring i kombination med egenkontroll.
AMA

För produkter som inte omfattas av krav på prestandadeklaration enligt byggproduktförordningen (CPR) ska verifiering ske enligt nivå 1-4 nedan. Om krav på nivå inte anges för en sådan produkt ska verifiering ske till lägst nivå 4.

Nivå 1

Certifierade produkter
Certifiering ska vara utförd av organ som ackrediterats av ackrediteringsorgan och som kan visa att de uppfyller och tillämpar kraven i SS-EN ISO/IEC 17011. Organet ska vara ackrediterat för att certifiera, prova eller bedöma aktuell produkt.

Nivå 2

Tillverkarförsäkran i kombination med certifierat kvalitetssystem

Som ersättning för detta godtas även certifiering enligt nivå 1.

Nivå 3

Tillverkarförsäkran i kombination med provning vid ackrediterat organ

Som ersättning för detta godtas även certifiering enligt nivå 1 eller verifiering enligt nivå 2.

Nivå 4

Tillverkarförsäkran i kombination med egenkontroll
Verifiering, det vill säga tillverkardeklaration, ska ske på basis av krav som anges för respektive produkt.

Som ersättning för detta godtas även verifiering enligt nivå 2 och nivå 3 samt certifiering enligt nivå 1.

Figur 3. Verifiering av överensstämmelse med krav på produkter, AMA Anläggning YE

Texten i Figur 2 hänvisar även till tabell 3.1–1 gällande betongens sammansättning, och tabell 3.1–2 gällande nötningsegenskaper i samma dokument (TDOK 2013:0532) och visas här nedan i Figur 4.
3 Krossad betong

3.1 Allmänt

Krossad betong indelas i fyra kvalitetsklasser beroende på beståndsdelarna i det återvunna materialet enligt tabell 3.1-1.

Tabell 3.1-1 Klassificering av renheten i krossad betong

<table>
<thead>
<tr>
<th>Kvalitetsklass</th>
<th>Klassificering av sammansättning på återvunnen ballast (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krossad betong</td>
<td>Betong, betongvaror, murbruk, betong murverk (%)</td>
</tr>
<tr>
<td></td>
<td>Obundna material, sten, hydrauliskt bundna material (%)</td>
</tr>
<tr>
<td></td>
<td>Lättviktsmaterial (cm³/kg)</td>
</tr>
<tr>
<td></td>
<td>Övrigt material: kohesiva (ex. lera och jord), diverse metaller, trä, plast och papper (%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Klass</th>
<th>$R_{C}$</th>
<th>$R_{CM}$</th>
<th>$FL$</th>
<th>$X$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$R_{C90}$</td>
<td>$R_{CM95}$</td>
<td>$FL_2$</td>
<td>$X_1$</td>
</tr>
<tr>
<td>2</td>
<td>$R_{C90}$</td>
<td>$R_{CM95}$</td>
<td>$FL_2$</td>
<td>$X_1$</td>
</tr>
<tr>
<td>3</td>
<td>$R_{C70}$</td>
<td>$R_{CM90}$</td>
<td>$FL_5$</td>
<td>$X_1$</td>
</tr>
<tr>
<td>4</td>
<td>$R_{C50}$</td>
<td>$R_{CM70}$</td>
<td>$FL_{10}$</td>
<td>$X_1$</td>
</tr>
</tbody>
</table>

(1) Enligt SS-EN 13242 Ballast for unbound and hydraulically bound materials for use in civil engineering work and road Kravet på nötningsegenskaper kan ersättas med krav på betongkvalitet enligt tabell 3.1-2. En betong med hög tryckhållfasthet är jämfört med att den krossade betongen har ett lågt micro-Devalvärde.

Tabell 3.1-2 Nötningsegenskaper/Betongkvalitet i krossad betong

<table>
<thead>
<tr>
<th>Klass</th>
<th>Micro-Deval</th>
<th>Dokumenterade uppgifter Hållfasthetsklass</th>
<th>Tryckhållfasthet kärnor (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-värde (3)</td>
<td>K-värde Mpa</td>
<td>MPA</td>
</tr>
<tr>
<td>1</td>
<td>≤ 25</td>
<td>≥ C 30/37</td>
<td>≥ K40</td>
</tr>
<tr>
<td>2</td>
<td>≤ 35</td>
<td>≥ C 20/25</td>
<td>≥ K25</td>
</tr>
<tr>
<td>3</td>
<td>≤ 50</td>
<td>≥ C 12/15</td>
<td>≥ K12</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(2) Klasser för tryckhållfasthet, enligt SS-EN 206-1.


Detta innebär att sammansättningen minst måste uppfylla kraven för klass tre i tabell 3.1-1 och nötningsegenskaperna måste uppfylla kraven för klass två i tabell 3.1-2.
Angående packning av betongen hänvisas till TDOK 2013:0532 avsnitt 3.3.2 vilket presenteras här nedan i Figur 5.

![Table 3.3-1](image)

**Figur 5. TDOK 2013:0532 avsnitt 3.3.2, krav på utförande.**

Angående kontroll av det färdiga lagret hänvisas till avsnitt 3.3.3.1 i TDOK 2013:0532, se Figur 6.
2. FÖRSTÄRKNINGSLAGER

Figur 6. TDOK 2013:0532 avsnitt 3.3.3.1

Här hänvisas till ytterligare ett dokument, texten från detta dokument tas inte med här eftersom dessa krav på provtagning är desamma som för krossat berg, det medför alltså inget extra arbetsmoment.

I koden för undre förstärkningslager kategori B (DCB.12) står ingenting om krossad betong, men eftersom vägar av kategori B har lägre krav än vägar av kategori A kan man anta att dessa regler gäller även här, eller lägre krav, men det finns inga föreskrifter.

Texten från TDOK 2013:0532 avsnitt 3.4.1 visas i Figur 7 och Figur 8.
3.4 Förstärkningslager till belagda vägar

3.4.1 Levererat material

Samtliga inköpta material med sorteringen ≤ 0/90 ska vara deklarerade (CE-märkta) enligt SS-EN 13242 “Ballast för obundna och hydrauliskt bundna material till väg- och anläggningsbyggande” med tillverkarförsäkran enligt användning utan höga säkerhetskrafter (system 4) och enligt SS-EN 13285 ”Obundnaöverbyggnadsmaterial, Specifikation”.

Samtliga material med sorteringen > 0/90 ska vara deklarerade med tillverkarförsäkran enligt AMA Anläggning, nivå 4.

3.4.1.1 Krav på material

Materialegenskaper beskrivna i avsnitt 3.4.1.1.1 - 3.4.1.1.3 ska vara deklarerade.

Material till förstärkningslager innehållande annat än stenmaterial som ballast i betongen ska uppfylla krav på frosthalka enligt ”Obundna lager för vägkonstruktioner” (TDOK 2014:0530) avsnitt 4.1.1.

3.4.1.1.1 Klassificering av sammansättning på återvunnen ballast

Materialet ska uppfylla kvalitetsklass 1 eller 2 enligt tabell 3.1-1.

Figur 7. TDOK 2013:0532 avsnitt 3.4.1

Informationen i 3.4.1 är densamma som för skyddslager (Figur 2). Om ballasten i betongen är av annat slag än sten ska det uppfylla krav på frosthalka. Angående betongens sammansättning ska den uppfylla kraven för klass 1 eller 2 enligt tabell 3.3–1 (Figur 4). Krav på kornstorleksfördelning och nöttingsegenskaper visas i Figur 8.
3.4.1.2 Kornstorleksfördelning

Kornstorleksfördelningen ska bestämmas enligt SS-EN 933-1 med metoden torrsiktning med förgående tvättning. Material > 125 mm provas med tolkar.

Kornstorleksfördelningen för förstärkningslager till flexibla konstruktioner ska uppfylla kraven enligt Tabell 3.4.1. Kornstorleksfördelningen ska ligga mellan normalt undre och övre värde och får vara in en av de yttre zonerna (högsta/lägsta värde).

Övre kornstorleksgränser (D) ska deklareras och andelen överkorn på sikten D i viktprocent inte får överstiga 20 %.

D får inte överstiga halva lagertjockleken.

<table>
<thead>
<tr>
<th>Sikt mm</th>
<th>0.063</th>
<th>0.25</th>
<th>1</th>
<th>4</th>
<th>16</th>
<th>31.5</th>
<th>63</th>
<th>90</th>
<th>125</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td>Högsta övre värde</td>
<td>7</td>
<td>14</td>
<td>22</td>
<td>40</td>
<td>64</td>
<td>90</td>
<td>98</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Normalt övre värde</td>
<td>6</td>
<td>10</td>
<td>16</td>
<td>32</td>
<td>54</td>
<td>78</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Normal undre värde</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>26</td>
<td>42</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lägsta undre värde</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>14</td>
<td>28</td>
<td>35</td>
<td>43</td>
<td>80</td>
<td>90</td>
</tr>
</tbody>
</table>

Tabell 3.4-1 Krav på kornstorleksfördelning för förstärkningslager till flexibla konstruktioner

3.4.1.3 Nötningsegenskaper (micro-Devalvärden)

Nötningsegenskaperna ska deklareras enligt SS-EN 13242 och ska minst uppfylla kraven för kategorin M15: 25.

Om materialet inte trafikeras av mer än enstaka tunga fordon (totalvikt över 3,5 ton) under byggnation kan micro-Devalvärden uppgå till 35.

Kravet på nötningsegenskaper kan ersättas med krav på betongkvalitet enligt tabell 3.1-2.

Figur 8. Kornstorleksfördelning och nötningsegenskaper enligt TDOK 2013:0532


Packning av krossad betong
Förstärkningslager av krossad betong ska packas enligt Alternativa material för vägkonstruktioner, TDOK 2013:0532, avsnitt 3.4.2.

Här gäller exakt samma värden som för skyddslager, se tabell 3.3–1 i Figur 5.

Kontroll
Förstärkningslager av krossad betong
Material i färdigt lager av krossad betong ska provas och uppfylla krav enligt Alternativa material för vägkonstruktioner, TDOK 2013:0532, avsnitt 3.4.3.1.
3.4.3 Krav på färdigt lager

3.4.3.1 Krav på material

Provtagning efter utförandet ska utföras på färdig lageryta enligt ”Provtagning av obundna material” (TDOK 2014:0151).

Efter provtagning får inte lagerytan justeras eller packas. Proven ska tas på hela lagertjockleken.

Krav ska vara uppfyllda kort innan nästa lager får påföra. De uppmätta egenskaperna hos respektive lager får inte hinna förändras väsentligen efter kontrollen.

Om materialet är produktcertifierat enligt AMA Anläggning avsnitt YE Nivå I för nödingsegenskaper anses krav för kontroll på färdigt lager vara uppfyllda om deklarerade värden uppfyller kraven i detta avsnitt.

Figur 9. Provtagning på färdigt lager enligt TDOK 3013:0532 3.4.3.

Här står samma sak som för skyddslager (Figur 6) dvs. krav på provtagning är desamma som för krossat berg, det medför alltså inget extra arbetsmoment. Det sista stycket finns dock inte med i kraven för skyddslager.

Förstärkningslager kategori B och kategori C

Liksom för skyddslager står här inget specifikt om krossad betong men eftersom båda dessa kategorier har lägre krav än kategori A kan man anta att kraven är lägre.