The use of recycled concrete aggregates in the Norwegian building and construction industry

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1. INTRODUCTION

Though the reduction of construction and demolition waste (C&D-waste) through recycling and reuse has received increased attention in the recent years, it is still not standard practice in Norway. However, changes in the Norwegian building and construction industry in the last 4-5 years towards more recycling and reuse, utilizing the C&D-waste for new construction, follows the trend seen in many countries around the world.

Lack of reliable C&D-waste statistics with respect to both the amount of waste generated on an annual basis in each region and the split between the various waste fractions, makes it difficult to measure the current level of C&D-waste recycling in Norway. Annual C&D-waste production in Norway, however, is approximately 1,5 mill. tons per year with about 70 % (1,1 mill. tons per year) consisting of concrete and masonry rubble (Statistics Norway, 1999). This is low compared to most EU countries, Mehus et. al. (2000). Rough estimates indicate current levels of recycling and reuse in Norway to be 10-20 %.

This is significantly less than countries like The Netherlands and Denmark. Then again, Norway hasn't had quite the same motivation as other countries. Norway is scarcely populated with only 4,5 mill. inhabitants spread out over large areas. At the same time, there is extensive access to primary raw materials, such as large natural aggregate reservoirs. On the other hand, reduced consumption of primary raw materials controlled handling of hazardous waste, and less waste landfilled are important objectives for the Norwegian authorities as well. The Norwegian building and construction industry recently published a national action plan for C&D-waste setting several ambitious objectives, BNL (2001). Specifically with respect to recycling, the industry's target is that by 2005 no more than 30 % of the C&D-waste should be landfilled annually.

In 1998, approximately 10 years after European countries like The Netherlands and Denmark lead the way, the first commercial recycling facility opened in Oslo. BA Gjenvinning, a produce and sell recycled concrete aggregate (RCA) from heavy C&D-waste (concrete and masonry rubble). However, lack of sufficient technical documentation and reference projects soon proved to be yet another obstacle to the use of RCA in Norway.

2. RESIBA

2.1 Objective and organization

The Norwegian research and development project RESIBA – Recycled Aggregates for Construction and Building (1999-2002) aimed at making RCA a competitive product for various applications within the Norwegian building and construction industry. The main objective of RESIBA was to encourage long-term use of RCA by:

- Disseminating new knowledge and results obtained in the RESIBA-project through systematic documentation and demonstration projects using RCA.
- Actively applying existing knowledge and experience on recycled building materials from other various projects both nationally and internationally.

EcoBuild, a five-year development program initiated by the Norwegian building and construction industry to increase the environmental efficiency of the industry, funded the RESIBA-project together with the project partners. The RESIBA-project included key representatives from the customer base, the producers, the public sector, and the research sector. The partners were Veidekke ASA (contractor), Norwegian Building Research Institute, BA Gjenvinning AS, Norwegian Public Road Authorities, Kontrollrådet for Betongprodukter (Norwegian certification organization), City of Oslo, Akershus County Municipality and Optiroc AS (building block manufacturer).

2.2 Work packages

The project was divided into three work packages:

- **Work package 1: Declaration and quality control**
  The aim was to produce a proposed system with parameters and routines for the quality control of RCA. This required extensive testing of important material properties and environmental leaching characteristics of RCA in order to document the main properties and possible environmental influences of the product
- **Work package 2: Demonstration projects**
  The aim was to evaluate the use of RCA in already completed construction projects and to launch various demonstration projects investigating the use of RCA in roads, trenches and different types of concrete structures.
- **Work package 3: Dissemination of results**
  The aim was to make knowledge and experience from the project widely available through a project web site, technical reports, articles, papers, seminars, courses etc.

3. DEMONSTRATION PROJECTS

3.1 Unbound use of recycled aggregates

A wide range of demonstration projects was initiated using RCA for various bound and unbound applications. As has been seen in countries like The Netherlands and Denmark unbound application in road and highway construction is expected to be the most common and profitable. For unbound applications of RCA the demonstration projects initiated were:

3.1.1 Roads and parking lots

In August 2000 the Oslo Public Roads Administration opened a new motorway through the Svartdal tunnel. A 50 m test section was established outside of the tunnel using approximately 600 tons of RCA 20-120 mm as sub-base. The thickness of the sub-base layer was approximately 0,9 m. In addition, a 50 m reference section was established using natural aggregates in the sub-base layer. Plate loading tests were performed, measuring the modulus of elasticity of the two test sections. In addition, the two test sections are currently being monitored measuring rut depth and the longitudinal evenness of the road surface.

Oslo Sporveier's new tramline over Gaustadbekkdalen in Oslo, completed in 1999, included the use of approximately 4000 m^3 of RCA as base material on top of a lightweight filling, and as backfill behind retaining walls. The project has been monitored by RESIBA, measuring deformation of the RCA base layer.

RCA has also been successfully used in 1996 as a base layer at a bus parking at Klemetsrud in Oslo, as backfill in drainage trenches at Skullerud in Oslo in 1997 and in pedestrian/cycle paths in Oslo. All projects are presented by Myhre et. al. (2002).

3.1.2 Trenches and backfills

Full scale laboratory testing conducted by the Norwegian Building Research Institute (NBI) indicated that RCA would function well as backfill materials in the pipe zone in utility trenches. The testing included various full-scale test set-ups exposing RCA to mechanical loading (simulating traffic load) and high volume water drainage.

In a demonstration project, Asker municipality used about 1000 tons of RCA (10-20 mm) as backfill in a 600 m utility trench for water and gas drainage from a landfill, Mehus et al. (2002) and Ingebriktsvold, Mehus (2000). The project has been closely monitored measuring deformation at various levels and locations along the trench.

Figure 1 Left: RCA as sub-base in the Svartdal tunnel in Oslo.
Right: Landfill in Asker using RCA as backfill in a 600 m utility trench.

3.2 Bound use of recycled aggregates

3.2.1 Concrete

During the construction of a new parking garage at Fornebu outside Oslo, the contractor, Veidekke ASA, incorporated the use of RCA by replacing 20 % of the coarse aggregate in the concrete foundations, Lahus et. al. (2002a and 2002b). Concrete production and casting of the foundations were successful, and the laboratory test results show that the concrete met the material properties as specified. Laboratory testing of concrete using up to 100 % RCA has also yielded positive results.

3.2.2 Shotcrete

One of the world's first employments of shotcrete incorporating RCA can be found at Oslo Sporveier's new tramline over Gaustadbekkdalen in Oslo, completed in 1999, Farstad, Hauck (2001), Hauck, Farstad (2001), Lahus et al. (2002a). The vertical sides of an EPS lightweight filling is protected by 100 m^3 of shotcrete in witch to 20 % of the sand was replaced by RCA. The contractor, Veidekke, successfully conducted the spraying, and the shotcrete met the material properties as specified. Testing included the determination of fresh shotcrete properties, mechanical properties, and durability characteristics.

3.2.3 Building blocks

Optiroc AS has produced Leca masonry sound insulation blocks using 30 % RCA, 4-10 mm. Laboratory testing demonstrate that all specifications for the Leca masonry sound insulation blocks are met, Lahus et al. (2002a).

Figure 2 Left: Concrete with RCA in foundations at Fornebu, Oslo.
Middel: Shotcrete with RCA in Gaustadbekkdalen, Oslo.
Right: Leca's building blocks with 30 % RCA.

In order to bring together the applications and to use RCA on a larger scale, at the conclusion of the RESIBA-project, RCA was included in both unbound and bound applications building a new high school in Sørumsand.

4. NEW HIGH SCHOOL IN SØRUMSAND

4.1 Project description

The new high school currently being built by Akershus County Municipality in Sørumsand just outside the city of Oslo was selected as the final demonstration project initiated by RESIBA. The new school building will be approximately 13 000 m^2. Construction started the summer of 2001, and the school will be ready for use by students during the fall of 2003. The high school building incorporates the use of RCA for unbound and bound applications, utilizing the results obtained through laboratory and field-testing in the RESIBA-project.

The use of RCA in the new building has been carried out in close cooperation with the design engineer, the contractor, the RCA supplier, and the concrete ready mix plant. The decision was made to include the use of RCA at an early stage, which allowed for recycled aggregates to be included as the main alternative in the bidding documents for the contractor.

4.2 Use of RCA

For the cast in place concrete (C35), in the foundations and in half the basement walls and columns, 35 % of the coarse aggregate was replaced with 10-20 mm RCA. A total of 800 m^3 concrete with RCA was used. The remainder of the basement was cast using 100 % natural aggregates. Extensive testing of the aggregates properties, the fresh concrete properties and the hardened concrete properties was conducted. To avoid the risk of any future complications, concrete with RCA was not used for sections of the structure expected to be exposed to freeze-thaw action. Test results later showed, however, that the concrete with 35 % coarse RCA had excellent freeze-thaw resistance, Mehus, Hauck (2002), Lahus et al. (2002a). Hardened concrete properties were comparable, and concrete production and casting was conducted without any problems. Visually, the concrete with 35 % RCA looks just as even colored as the concrete with 100 % natural aggregates. The use of 35 % RCA did not cause any noticeable increase in cracking.

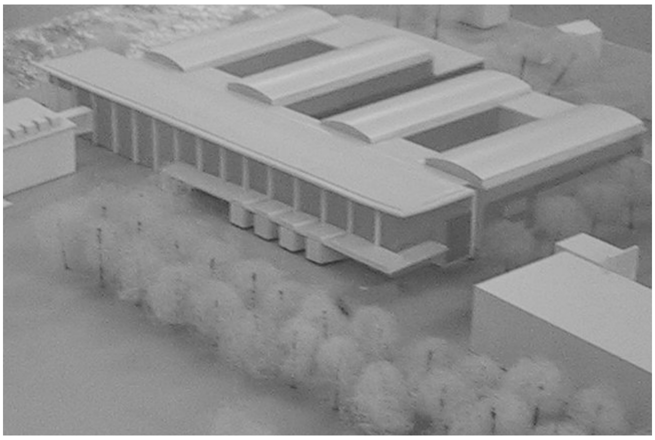

Figure 3 Left: Model of new high school building at Sørumsand
Right: Concrete walls and columns with 35 % coarse RCA.

In addition, large volumes of RCA were used as a sub-base between foundations and as a backfill against basement walls. Sound-insulation building blocks with 30 % RCA will also be used, and RCA will replace be used as road-base and sub-base in parking lots.

5. RESULTS

The RESIBA-project has successfully documented that RCA is a viable alternative to natural aggregates for a wide range of applications. As in most other countries, unbound applications such as road and utility trenches are expected to be the most important areas of use.

In general, the technical results from the various laboratory and demonstration projects using RCA are overall positive. Material properties such as mechanical strength, density, and water absorption are significantly different compared to natural aggregates. However, important functional characteristics such as deformation stability, load distribution, permeability, etc. are similar to those of natural aggregates. Laboratory testing of concrete replacing up to 100 % of the coarse aggregate with RCA also yielded positive results. Concrete with as much as 35 % of the coarse aggregate replaced by RCA was successfully used in regular construction at Sørumsand High School. None of the structures used as demonstration projects have suffered any kind of deterioration or damage due to the use of RCA as an alternative to natural aggregates. Also, the results reported by Engelsen et. al. (2002a and 2002b) with respect to potential leaching of harmful substances, showed that the RCA tested had no significant environmental impact.

The RESIBA-project has clearly documented a need for a system of quality control and declaration, such as, for example, the certification scheme proposed by the RESIBA presented by Karlsen et. al. (2002a and 2002b).

For most of the demonstration projects, the use of RCA ended up reducing the costs compared to natural aggregates. This is, of course, due to the lower cost per m^3 of RCA compared to natural aggregates (about 50 %). Transportation is crucial, however, and will be the deciding factor for the majority of projects. The availability of RCA and the ability to guarantee a steady supply to the construction site will also be important. Handling and construction using RCA did not cause additional labor or any other special problems on the construction site.

6. GUIDELINES FOR THE USE OF RECYCLED AGGREGATES

The RESIBA-project had put a strong emphasis on the dissemination of results. A variety of papers, articles have been published and detailed technical results are presented and discussed in depth in a series of seven project reports. In addition, a summary of the results and recommendations from RESIBA is presented in a 20-page booklet titled Guidelines for the use of RCA. The guidelines are not intended to provide detailed design specifications for consultants, but rather give a general orientation with easily accessible information about the most important areas of use for RCA in the Norwegian construction industry. The guidelines are available for download from the RESIBA website (www.byggforsk.no/prosjekter/RESIBA). The overall purpose of the guidelines is to increase the general level of knowledge of RCA as a viable alternative to natural aggregates for a wide range of applications, subsequently, increasing the use of RCA. The guidelines provide a two page overview of each of the following areas of use: Roads and parking lots, utility trenches, backfill an sub-base, concrete, shotcrete, building blocks.

These overviews also include references to and pictures from relevant demonstration projects, and references to technical reports published by the RESIBA project for more in depth technical information. The booklet includes a brief summary of the results with respect to potential problems with leaching of harmful substances. RESIBA's proposed system for declaration of RCA is also presented.

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