

SINTEF Building and Infrastructure    Børge Johannes Wigum (NTNU)

# Hokksund Quarry – Review of the aggregate production

COIN Project report 33 – 2011



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FA 2 Competitive constructions

SP 2.3 High quality manufactured sand for concrete

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## Preface

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This study has been carried out within COIN - Concrete Innovation Centre - one of presently 14 Centres for Research based Innovation (CRI), which is an initiative by the Research Council of Norway. The main objective for the CRIs is to enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups.

The vision of COIN is creation of more attractive concrete buildings and constructions. Attractiveness implies aesthetics, functionality, sustainability, energy efficiency, indoor climate, industrialized construction, improved work environment, and cost efficiency during the whole service life. The primary goal is to fulfill this vision by bringing the development a major leap forward by more fundamental understanding of the mechanisms in order to develop advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.

The corporate partners are leading multinational companies in the cement and building industry and the aim of COIN is to increase their value creation and strengthen their research activities in Norway. Our over-all ambition is to establish COIN as the display window for concrete innovation in Europe.

About 25 researchers from SINTEF (host), the Norwegian University of Science and Technology - NTNU (research partner) and industry partners, 15 - 20 PhD-students, 5 - 10 MSc-students every year and a number of international guest researchers, work on presently 5 projects:

- Advanced cementing materials and admixtures
- Improved construction techniques
- Innovative construction concepts
- Operational service life design
- Energy efficiency and comfort of concrete structures

COIN has presently a budget of NOK 200 mill over 8 years (from 2007), and is financed by the Research Council of Norway (approx. 40 %), industrial partners (approx 45 %) and by SINTEF Building and Infrastructure and NTNU (in all approx 15 %).

For more information, see [www.coinweb.no](http://www.coinweb.no)

Tor Arne Hammer  
Centre Manager

## Summary

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Hokksund Quarry was visited and reviewed in order to make assessment of the potential of using the current 0/4mm aggregate in concrete from the quarry as it is today, i.e. already crushed and stored with today processes.

In this report the production process is described, along with consideration regarding challenges regarding storage and segregation of 0/4 mm materials.

Some preliminary results on concrete mix design are presented, along with some future scenarios for optimized production of manufactured sand (0/4mm).

Aggregate materials from Hokksund quarry have been delivered to Tampere, Finland for test VSI crushing at the test plant of Metso. Subsequent concrete mix design with those materials will be carried out at NTNU, Trondheim during spring 2011.

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## 1 Introduction

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### 1.1 Background

This study has been carried out within COIN - Concrete Innovation Centre - one of presently 14 Centres for Research based Innovation (CRI), which is an initiative by the Research Council of Norway. The main objective for the CRIs is to enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups.

A subproject; FA 2.3 High quality manufactured sand for concrete, is carried out as part of COIN. The justification for the subproject is the situation that the world's resources of natural aggregates are getting scarcer. The subproject aims therefore to produce crushed fine aggregates (manufactured sand) with optimal properties for concrete. Focus point are; geological origin, production, optimal grading curves – no waste materials, handling, characterization and economy.

Kolo Veidekke participates in this subproject with the main objective to contribute in develop a concept for utilisation of manufactured sand with various properties for use in concrete.

More specific the objectives are:

1. Make assessment of the potential of using the current 0/4mm material from the Hokksund quarry as it is today, i.e. already crushed and stored with today processes.
2. Obtain knowledge about properties of the current 0/4mm material regarding utilisation in concrete, i.e. mineralogy, grain shape, filler properties etc.
3. Based on the properties of the material, make an assessment of the most critical properties for us in concrete.
4. Consider the potential of the material from Hokksund quarry regarding potential optimization of material by crushing- and classification processes.
5. Obtain knowledge of optimal mix design (including use of admixtures) for production of concrete.

In order to start the process of reaching these objectives, as part of the COIN subproject, 2.3, Lillian Uthus Mathisen (Kolo Veidekke) and Børge Johannes Wigum (NTNU) visited Hokksund Quarry 13th January 2010. The quarry is operated by Kolo Veidekke and a meeting was arranged with the production manager; Thor Inge Torsholt.

## 1.2 The quarry and the market situation

The quarry is described as a typical inland Norwegian quarry with an annual production of approximately 300.000 tons. The mass balance of the various aggregate products today is considered good, with the main focus on producing the size fraction 8/11mm.

The main clients are local- and regional contractors, along with asphalt and concrete producers. The aggregate size fractions; 0/4, 4/8, 8/11, 11/16, 8/16 and 16/22mm are certificated for application in asphalt and concrete. The aggregate size fraction 31.5/63mm is certificated for use as railway ballast.

In a normal year the production of manufactured sand (0/4mm) is in the order of 40.000 tons. Of this approx. 10.000 tons are delivered to the nearby asphalt producer; NCC. Additionally, 10.000 tons are delivered to various applications, e.g. 5.000 tons to a horse racetrack where the material has exhibited excellent properties. The manufactured sand has until now not been used in local concrete production, which use natural sand aggregates.

The quarry is storing approx. 200.000 tons of materials in the 0/4mm size fractions, and this volume is increasing annually by 20.000 tons.

The surplus of this material is the reason why Hokksund Quarry wants to consider possibilities to utilise manufactured sand in the concrete production. At the moment, the 0/4mm size fraction of manufactured sand is not certificated for use in concrete.

A local concrete producer; "Loe Rørprodukter AS and Loe Betongelementer AS" is positive to consider the use of manufactured sand in their production. They have recently invested about NOK 120 millions in new production facilities. They would like to consider the possibilities of starting to add manufactured sand in their concrete production. Current ideas are to start with e.g. 20-30% of manufactured sand and subsequently increase this until they reach possible problems. Then they could reduce the amount down to a satisfactory level.

In various concrete products produced by Loe, e.g. pipes and manholes for the municipality, the concrete do not require high flow properties, i.e. the concrete is dry. In previous work by SINTEF, it has been shown the beneficial effect of adding up to 50% of manufactured sand in such concrete products at Loe. It was also shown that such concrete gained higher earlier strength.

The landowners in the area are positive of using the manufactured sand, however, local concrete ready mix producers are currently negative to this application.



## 2 The production process

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The raw material in the quarry is a rock defined as a Gneiss Diorite. The aggregate production is divided into 3 different crushing and screening units, with a production of 200 tons/hour;

1. The coarse crushing unit
2. The intermediate crushing unit
3. The fine crushing unit



Figur 1. The production process.



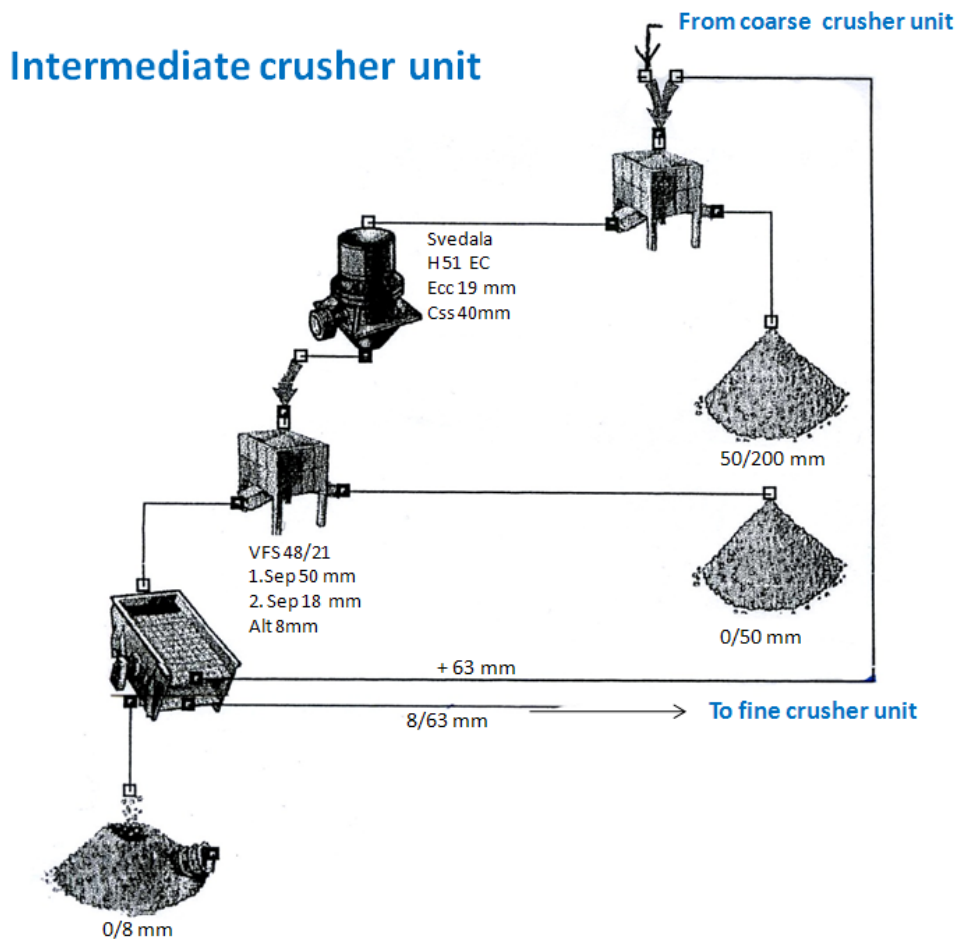
## 2.2 The intermediate crushing unit

Feed materials, 20/200mm, coming from the coarse crusher unit, are screened and size fraction 50/200mm are stored. Materials <50mm are feed into a Svedala cone crusher with a closed side setting of 40 mm. The level of aggregate materials in the cone crushers are governed by photocells, which ensure the crushers always are choke feed.

Subsequent to the crusher, the materials are screened and the size fraction 0/50mm is stored. In a final screen, materials >63mm are sent in closed circuit back to the first screen. Materials 8/63mm are further fed to the fine crusher unit.

In order to adjust/optimize the feed opening, the return materials are inspected. The operators have the experience to know what the optimum feed opening shall be.

The intermediate crushing unit is considered harmonised concerning the current market situation. It would be a challenging task to start to make adjustments with different size fractions.



Figur 3. The intermediate crusher unit.

### **2.3 The fine crushing unit**

Two cone crushers stand in parallel, with stroke 22 mm and feed opening 15 mm.

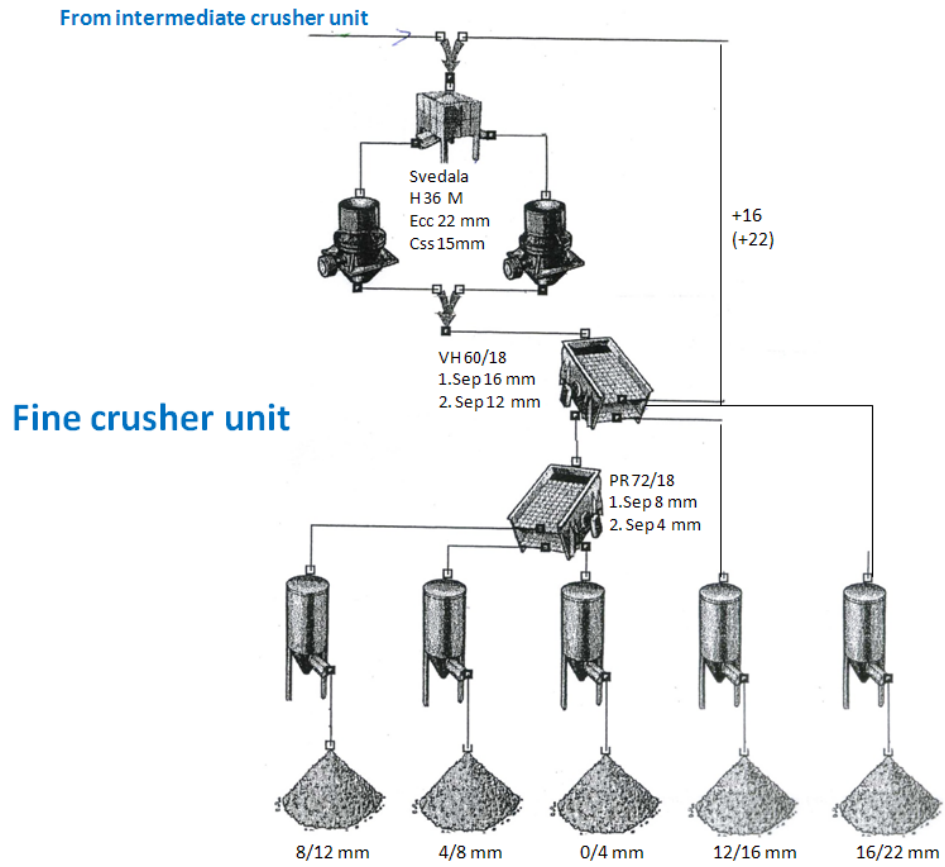
Until now it has been emphasised on the quality of the size fractions; 8/11 mm and 12/16 mm. Less focus has been on the quality of the 0/4 mm size fraction. It is the experience that when the feed material is 22 mm, the end product of 0/4 mm will be more flaky than when the feed material is 16 mm. However it is not profitable to use 16 mm as feed material due to the mass balance.

A Barmac VSI crusher was used some 25 years ago. The experience was a better cubical shape of the aggregate particles; however, more fines were produced.

The quality of the feed material from the intermediate plant, e.g. 8/63 mm governs the quality of the final products in the fine crusher plant. It has also been experienced great impact on the particle shape with increased wear of crusher parts.

It has been considered to try to split the fine material on 2mm by ordinary sieves, producing e.g. 0/2mm and 2/8mm. It is believed that this could be economical feasible and increase the volume of the sale of the products. By reducing the fine fraction to 0/2mm, it is also believed that the problem of segregation in the 0/4mm fraction will decrease.

Regarding sieving it has been experienced that the moisture content in the fine aggregates are of critical importance. If the moisture content is around 2% there is a great risk of cladding, while moisture content around 0.5% creates problem with segregation.



Figur 4. The fine crusher unit.

### 3 Storage and segregation

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A memo is presented by Kolo veidekke, 26.10.2009, where the aim is to review routines regarding storage and handling of material 0/4mm at Hokksund Quarry, to reduce variation and segregation.

Among others, the following was reported:

- It is observed significant segregation in the 0/4mm materials after screening and transportation of materials to the silos. In the silos, which has a storage capacity of maximum 30 tons, it is observed that the finest part of the 0/4mm materials (60-70%) concentrate in one side of the silo, while the coarsest part of the materials concentrate in the other side.
- The four discharge trapdoors at the silo have a square shape with a flat bottom, and it is regarded that these configuration do not contribute to avoid the separation, as the discharge procedures are today. Discharging of the material from the silo to an intermediate storage area is done by dump trucks. It is tried to handle the material in a dry condition from the silo to the intermediate storage area. In the storage area, the material is mixed into stockpiles of layer thickness of 2 to 3 meters. However, when handling material from silo used in the asphalt production, it is tried to have the material with natural moisture content as the experience has showed that this procedure leads to less separation than for dry material. For long term storage, the material is stockpiled in a step stockpile – approx. 20 meters high.
- For sampling of the material, samples are obtained in various parts of the intermediate storage area and mixed in the ground. This is carried out according to procedures at the quarry and carried out by the same operator each time.

The following recommendations were reported to be considered for adjustment in the processes:

- The feed of material from the screen to the storage in the silo appears to be a bottleneck. It is necessary to govern the feed of material and distribute the material over the entire cross-section of the silo. This will require more space between the screen and the top of the silo, either by lifting the screen or lowering the basement under the silo.
- The existing four discharge trapdoors should be connect in series and operated simultaneously with full opening at loading.
- The intermediate storage area must be moved or extended. The basement under the storage area must have a hard surface, enabling drainage of all surface water. Necessary to have procedures for clean handling of the material with wheeled loader. The material should as much as possible be handled in dry condition and mixed in stockpile with height of 1.5 meters. A second layer of stockpile could be applied; however, it should be avoid having the second layer wider than the bottom layer. When taking material from the stockpile it should be taken out from the top layer first and mixed on the ground prior to delivering to the truck. It is believed that following these procedures will increase the security against segregation.

According to information from Thor Inge Torsholt, a storage tent has been purchased and will be put into service as dry storage area for the 0/4mm size fraction.

## **4 Future research on concrete mix design**

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Some preliminary concrete testing has been carried out with the manufactured sand from Hokksund Quarry. In total 5 different concrete mixes were tested at Rescon Mapei, where natural sand (0/8) from Lyngås were partly replaced with manufactured sand (0/4) from Hokksund. Coarse aggregate (11/16) from Steinskogen was applied. The target was to produce both ordinary concrete; B30 M60 D16, with a target slump of 200mm, and self-compacting concrete; SKB B30 M60. Preliminary results indicate that satisfactory results were obtained for a ordinary concrete, when replacing 20% of the sand with manufactured sand from Hokksund. However, when replacing 33% of the sand with manufactured sand, the consistency of the concrete was not satisfactory. The reason was believed to be due to increased friction of the manufactured sand, in addition to the effect of increased water absorption in the completely dry manufactured sand. However, the concrete mix with 33% manufactured sand, exhibit significant higher compressive strength after 2 days.

For the self-compacting concrete, satisfactory results were obtained when replacing 20% of the sand with manufactured sand, with slightly higher compressive strength after 2 days compare to the reference self-compacting concrete without replacement of manufactured sand.

## **5 Future scenario for optimized production of manufactured sand (0/4mm)**

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In order to optimise the future production of 0/4mm manufactured sand, several scenarios were discussed:

1. Installation of VSI crusher and air classifier.
2. Adjustments and configuration of the cone crushers – evaluate the potential of the cone crushers.
3. Optimise the storage condition – dry storage with procedures regarding storage and handling to avoid segregation.
4. Just start trials with the materials at Loe Concrete producer.



**SINTEF Building and Infrastructure** is the third largest building research institute in Europe. Our objective is to promote environmentally friendly, cost-effective products and solutions within the built environment. SINTEF Building and Infrastructure is Norway's leading provider of research-based knowledge to the construction sector. Through our activity in research and development, we have established a unique platform for disseminating knowledge throughout a large part of the construction industry.

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