Workshop on Manufactured Sand, Stavanger, Norway 20–21 October 2014

COIN project report 80 – 2015
Workshop on Manufactured Sand, Stavanger, Norway 20–21 October 2014

FA: Competitive constructions
SP 2.3 Production of high quality manufactured aggregate for concrete
MANUFACTURED SAND WORKSHOP

STAVANGER, NORWAY, OCTOBER 20TH AND 21ST 2014

SUMMARY OF PRESENTATIONS

COIN Version
November 2014
Introduction

This seminar on production and use of manufactured sand as concrete aggregates, is marking an end of the sub-project 2.3 on; “Manufactured sand”, within the research program; COIN - Concrete Innovation Centre. The vision of COIN is creation of more attractive concrete buildings and constructions. Attractiveness imwww.gooplies 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 fulfil 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.

COIN has been running for the last 8 year and is finalising this year. The program is financed by the Research Council of Norway, industrial partners, SINTEF Building and Infrastructure and Norwegian University of Science and Technology (NTNU).

The main aim of this Seminar is to create opportunity for professional development, for information sharing and dissemination. We want this Seminar to be an arena for interactive exchange of experiences between the participants, and invited speakers will present their presentations regarding one of the following topics:

- Production (extraction, crushing, sieving, washing)
- Cases of real activities
- Characterization and testing of fines
- Use of manufactured sand in concrete; mix design
- Resources, environmental issues and discussion about the future
Front row from left: Børge Johannes Wigum, Hernan Mujica, Sven-Henrik Norman, Berit Laanke
Second row, from left: Stefan Jacobsen, Espen Rudberg, Sverre Smeplass, Svein Willy Danielsen, Rolv Magne Dahl, Knut Li
Back row: Bård Dagestad, Reidar Velde, Odd Hotvedt, Marit Haugen, Rolands Cepuritis, Hans-Erik Gram, Oliver Patsch, Egil Velde, Serina Ng, Eoin Heron, Olav Hallset
Not present: Brynjard Lund-Andersen & Lillian Uthus Mathisen
## Participants

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<td>4 Danielsen</td>
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<td>5 Gram</td>
<td>Hans-Erik</td>
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<td>7 Haugen</td>
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<td>8 Heron</td>
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<td>18 Rudberg</td>
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<td>19 Smeplass</td>
<td>Sverre</td>
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<td>20 Uthus Mathisen</td>
<td>Lillian</td>
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<td>21 Velde</td>
<td>Reidar</td>
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<td>22 Velde</td>
<td>Egil</td>
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<tr>
<td>23 Wigum</td>
<td>Børge Johannes</td>
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*Manufactured Sand - Workshop*

Stavanger, Norway, October 20th and 21th 2014
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<td>“Engineered sand production with Vertical Shaft Impact (VSI) crushers and static air-classifiers”</td>
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<td>Tero Onnela</td>
<td>Metso</td>
<td>Sand solution equipment</td>
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<td>Sven-Henrik Norman</td>
<td>Sandvik</td>
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<td>Odd Hotvedt</td>
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<td>Eoin Heron</td>
<td>CDE Global Limited</td>
<td>Washing Manufactured Sands.</td>
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<td>Egil Velde</td>
<td>Velde Pukk</td>
<td>An integrated concept of aggregate production and use.</td>
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<td>Sverre Smeplass</td>
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<td>Filler composition, a new tool to control concrete workability</td>
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<td>Sustainable concrete aggregate in perspective of the resources situation.</td>
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<td>Rolv Dahl</td>
<td>NGU</td>
<td>Current and future consumption and supply of building materials in Norway.</td>
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<tr>
<td>Olav Hallset</td>
<td>Norwegian Mineral Industry</td>
<td>Public Management of Geological Resources</td>
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# MANUFACTURED SAND - SEMINAR
Stavanger, Norway, October 20th and 21st 2014

## Schedule

### Monday 20th October

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<td>Børge Johannes Wigum, NTNU/Norcem</td>
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<td>2. Session - Real cases</td>
<td>Odd Hotvedt, Norsk Stein, Jelsa</td>
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<td>Sverre Smeplass, Skanska</td>
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### Tuesday 21st October

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### Lunch

- Monday 20th October
- Tuesday 21st October

### Excursion to Velde

- 15:30 - 18:00
MANUFACTURED SAND - SEMINAR
Stavanger, Norway - October 20\textsuperscript{th} and 21\textsuperscript{st} 2014

Concrete Innovation Centre (COIN)
- A centre for research based innovation

2007 – 2014; Closure Seminar

Marit Haugen – SINTEF
Svein Willy Danielsen – SINTEF
Rolands Cepuritis – NTNU/Norcem
Børge J Wigum – NTNU/Norcem

COIN - Concrete Innovation Centre

- COIN - one of 14 Centres for Research-based Innovation (CRI)
- The Research Council of Norway’s tool to stimulate the industry to further innovation by creating close alliances between research-intensive enterprises and prominent research groups
- SINTEF leading this 8 year centre (2007 – 2014) with a budget of more than 25 mill EUR, in cooperation with NTNU and industrial partners with their subcontractors, represent the whole value chain
Focus Areas

1) Environmental friendly concrete structures
2) Competitive construction
3) Technical performance

2.3 High quality manufactured sand for concrete

Stavanger 30.-31. Oktober 2008
2) Competitive construction

2.3 High quality manufactured sand for concrete
2) Competitive construction

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2.3 High quality manufactured sand for concrete

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<td>Onnela Tero</td>
<td>Metso</td>
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<td>Cepuritis Rolands</td>
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<tr>
<td>Dagestad Bård</td>
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<td>Dahl Rolf Magne</td>
<td>NGU</td>
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<td>Danielsen Svein Willy</td>
<td>SINTEF Byggforsk</td>
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<td>Gram Hans-Erik</td>
<td>Cementa</td>
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<td>Hallset Olav</td>
<td>Norsk Bergindustri</td>
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<td>Haugen Marit</td>
<td>SINTEF</td>
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<td>Heron Eidin</td>
<td>CDE Global Limited</td>
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<td>Jacobsen Stefan</td>
<td>NTNU</td>
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<td>Laanke Berit</td>
<td>SINTEF</td>
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<td>Li Knut</td>
<td>Franzeloss Pukk AS</td>
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<td>Lund-Andersen Brynjarp</td>
<td>Franzeloss Pukk AS</td>
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<td>Odd Hotvedt Odd</td>
<td>Norsk Stein</td>
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<td>Oliver Patsch Oliver</td>
<td>Norsk Stein</td>
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<td>Pedersen Bård</td>
<td>Statens vegvesen</td>
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<td>Rudberg Espen</td>
<td>Rescon Mapei</td>
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<td>Smepllass Sverre</td>
<td>Skanska/NTNU</td>
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<tr>
<td>Uthus Mathiesen Lillian</td>
<td>Kolo Veidekke</td>
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<td>Velde Reidar</td>
<td>Velde AS</td>
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<td>Velde Egil</td>
<td>Velde AS</td>
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<tr>
<td>Wigum Børge Johannes</td>
<td>NTNU/Norcem</td>
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# Manufactured Sand - Workshop

**Session 1: Crushing and screening of manufactured sand**  
Chair: Børge Johannes Wigum

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<tr>
<td>12:00 - 13:00</td>
<td>Lunch</td>
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<tr>
<td>13:00 - 13:30</td>
<td>Børge Johannes Wigum, NTNU/Norcem: Introduction</td>
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<tr>
<td>13:50 - 14:10</td>
<td>Tero Onnela, Metso: Sand solution equipment</td>
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<tr>
<td>14:10 - 14:30</td>
<td>Sven-Henrik Normag, Sandvik: Manufactured sand Solutions by Sandvik</td>
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**Session 2: Real cases**  
Chair: Svein-Willy Danielsen

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<td>14:30 - 14:50</td>
<td>Odd Hotvedt, Norsk Stein, Ålesund: Yearly production of 10 mill. tons aggregate. Challenges and possibilities regarding the sand production.</td>
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<tr>
<td>14:50 - 15:10</td>
<td>Eoin Heron, CDE Global Limited: Washing Manufactured Sands.</td>
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<tr>
<td>15:30 - 18:00</td>
<td>Excursion to Velde</td>
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<td>19:00</td>
<td>Dinner</td>
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**Session 3: Classification of fines – standardization concrete mix design**  
Chair: Børge Johannes Wigum

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<tr>
<td>08:40 - 09:00</td>
<td>Sverre Smeplass, Skanska: Filler composition, a new tool to control concrete workability</td>
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<tr>
<td>09:00 - 09:20</td>
<td>Hans-Erik Gram, Cementa: Sustainable production of fine particles from rock materials – a 2 year project in Sweden</td>
</tr>
<tr>
<td>09:20 - 09:40</td>
<td>Rolands Cepuritis, NTNU/Norcem: Methods for characterization of crushed filler properties and principles of proportioning concrete with these materials.</td>
</tr>
<tr>
<td>09:40 - 10:00</td>
<td>Hans-Erik Gram, Cementa: How to determine the influence of aggregate fillers on the yield stress and plastic viscosity of micromortar.</td>
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<tr>
<td>10:00 - 10:30</td>
<td>Coffee/discussion</td>
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**Session 4: Resources – Environmental issues – The future**  
Chair: Svein-Willy Danielsen

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<th>Time</th>
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<tr>
<td>10:30 - 10:50</td>
<td>Bård Dagseth, NorStone: Sustainable concrete aggregate in perspective of the resources situation.</td>
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<td>11:10 - 11:30</td>
<td>Olay Hallset, Norwegian Mineral Industry: Public Management of Geological Resources</td>
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<tr>
<td>11:30 - 12:00</td>
<td>Summary and discussion</td>
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<td>12:00 - 13:00</td>
<td>Lunch</td>
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**Stavanger, Norway, October 20th and 21th 2014**
Transportation of aggregates in Norway (2012); 110,000 tonn CO₂
- 1.1% of all transport
- 10% of cement
Engineered sand production with Vertical Shaft Impact (VSI) crushers and static air-classifiers

How to "crush sand"

20-30 NOK/t

0-8 mm

0.8 mm

0.2 mm
How to "crush sand"

Materials technology - the use of aggregates

Technological sales

Aggregate technology - the basic interdependency

Geology - the basis for aggregate resources

Production technology - the processing of aggregates

VSI – expected shape improvement

Barmac B5100SE VSI @ 70 m/s | FEED = 4/22 mm
VSI – expected shape improvement

- Average 60%

CRUSHABILITY

VSI – fines generation

- Fines content vs. quality of fines:

HIGH SS
LOW SS
Static air-classification - principles

Static air-classification - opportunities
Static air-classification - opportunities

![Graph showing cumulative % passing vs. particle size for different materials and fractions.](image)

- Feed
- GI fines
- C fines
- 0.150/2 mm
- 0.063/0.125 mm
- 20/60 µm
- 4/25 µm

HIGH SS

LOW SS

Static air-classification - opportunities

![Graph showing cumulative % passing vs. equivalent size for GI fines.](image)

- M
- Gn/Gr
- Q
- A
- L1
- L2
- D
- S
- A
- Gr/Gn

Slide 9 - 12.06.2014
Rolands Cepuritis

Slide 10 - 12.06.2014
Rolands Cepuritis
**Static air-classification - opportunities**

Modelled "Q fine" & "coarse"

- **ENGINEERED SAND** = VSI + air classification & fines optimization
- **Crushed agg. prod.**
  - Contribution Margin ~ 20-25%
- High contribution margin CRUSHED SAND;
- New AGGREGATE opportunity
  - high contribution margin crushed filler materials for:
  - CONCRETE production;
  - ASPHALT production (SMA);
  - Soil LIMING (dolomite & limestone);
  - etc.
Sandvik Sand Solutions
Sven-Henrik Norman
Sales manager

COIN seminar Oct 20-21
2014

Manufactured sand 2009-present

Globally:
Shortage of natural sand in some markets
Australia
India
Brazil

In common:
Concrete industry more positive towards alternatives to natural sand today than 2009
More knowledge through research?
Better additives?
Good marketing?

Sweden:
Shift towards manufactured sand
Main players, NCC, Skanska, Swerock all use or produce manufactured sand in concrete
South of Sweden, marine dredged sand from the Baltic sea still available
Government is being very restrictive towards allowing new natural sand & gravel pits

Stavanger, Norway, October 20th and 21th 2014
Sandvik Sand Solutions
Mobile or Stationary solutions?

Stationary
- Process control
- Rock properties
- Multiple crushing stages
- Dry process

Mobile
- Flexibility
- Close to source or end user
- Lower investment
- Re-sale value

Sandvik Sand
Mobile solution
Classification

Variation of sand product size distribution by different frequencies of the main fan

Variation of sand product size distribution by different frequencies of the separator fan (Main fan speed constant)

Schmidt Air Classifier range

Capacity figures for Air Classifier types

<table>
<thead>
<tr>
<th>Capacity figures for Air Classifier type</th>
<th>USGF FT Size (ft³/min)</th>
<th>Maximum capacity (tph)</th>
<th>Min. feed capacity (tph)</th>
<th>Weight (kg)</th>
<th>Cyclone diameter (mm)</th>
<th>Installed Power (kW)</th>
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<tr>
<td>USGF 25</td>
<td>8</td>
<td>40 - 50</td>
<td>4000</td>
<td>3650</td>
<td>2500 mm</td>
<td>25</td>
</tr>
<tr>
<td>USGF 20</td>
<td>8</td>
<td>40 - 50</td>
<td>4000</td>
<td>3650</td>
<td>2500 mm</td>
<td>20</td>
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<tr>
<td>USGF 25</td>
<td>12</td>
<td>60 - 75</td>
<td>6000</td>
<td>5150</td>
<td>3000 mm</td>
<td>30</td>
</tr>
<tr>
<td>USGF 25</td>
<td>16</td>
<td>90 - 110</td>
<td>9000</td>
<td>7150</td>
<td>4000 mm</td>
<td>40</td>
</tr>
<tr>
<td>USGF 32</td>
<td>20</td>
<td>100 - 130</td>
<td>10000</td>
<td>11000</td>
<td>4700 mm</td>
<td>60</td>
</tr>
<tr>
<td>USGF 40</td>
<td>20</td>
<td>120 - 150</td>
<td>12000</td>
<td>13000</td>
<td>5700 mm</td>
<td>80</td>
</tr>
<tr>
<td>USGF 50</td>
<td>20</td>
<td>150 - 180</td>
<td>15000</td>
<td>16000</td>
<td>6500 mm</td>
<td>100</td>
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NOTE: Figures calculated with feed 0.1% fines and separation at 600 μm and ca. 45% <60 μm in the coarse product.
The largest Costal Aggregate Quarry in Europe
**Capacity development**

*Million tons*

- **Capacity development graph**
  - Years: 1987 to 2014
  - Units: Million tons

**Fleet of 6 ships, 17,000 to 30,000 tons**

- **Image of ships**
  - Location: Stavanger, Norway, October 20th and 21th 2014
Primary crusher: 2800-3000 tph
- **Products**
  - 0/16
  - 0/5
  - 5/32
  - 25/125 (6 inch offshore)
  - 50/200 (8 inch offshore)
  - **Bedstone**
    (Separate production)
    - 0/2
    - 0/2 washed (0,06/2)
    - 2/5
    - 5/8
    - 8/11
    - 11/16
    - 16/22
    - 22/32
    - 16/32
    - 30/60

- **Distribution of products and excess products**
  - Offshore 17%
  - 0-16 19%
  - 5-16 3%
  - 0-5 3%
  - 16-22 5%
  - 16-32 5%
  - 22-32 4%
  - 30-60 2%
  - Armour stone 2%
  - V0-2 3%
  - Excess 0-2 2%
  - < 0.063mm 1%

**Stavanger, Norway, October 20th and 21th 2014**
Challenges related to fine material and market:

Large share of fine material products:

- 0/16 from blasting, primary-and secondary crusher steps
  - About 27% of total production
  - Main market: 0/32 (have to add 16/32)
  - Low price product
- 0/2 from tertiary plant, washed and unwashed
  - About 5% of total production (500,000 t)
  - Low price product and too small market
  - Have to deposit the excess
  - Limit in discharge volume: 150,000 t/year

Challenges related to the processing of the fine material:

1. Water and moisture!

- High and fluctuating moisture content in 0/16 from blasting, primary-and secondary crusher steps, from
  - Rain at the blast and the intermediate stock
  - Dust fighting
- Challenging screening
  - Splitting of 0/16 from primary plant in 0/5 and 5/16 not possible at high moisture content
  - Screening in tertiary plant, in particular the split at 2 mm.
  - Fines sticking to coarser particles.
Challenges related to the processing of the fine material:

1. Water and moisture!
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Dust fighting
Concrete production with 100% crushed materials 20 years ago

Aggregate
- Unwashed 0/2. High filler content 18-20 % < 0.063 mm, From cone crusher, poor shape
- Step graded curve, no 2/5 mm. Dmax 22 mm

Typical prescriptions
- C65, v/c < 0.60  310 kg cement 4 l P
- C65, v/c < 0.45,  420 kg cement 2.5 l P + 5 l SP

Possibilities related to fine material

The 0/16 from blasting, primary-and secondary plants (2.5 mill tons per year):

- Improve the particle shape of 0/16 by a VSI crusher
- Split into standard gradings by wet screening and wet sand processing. Control the grading of 0/2 precisely.

Produce:
- High value products (like from the tertiary plant)
- Manufactured sand
Possibilities related to fine material

The 0/2 from tertiary plants (0.5 mill tons pr. year)

- Improve the particle shape of 0/2 + 2/5 from tertiary plant by a VSI crusher
- Process in a dry or wet process, control the curve of 0/2 precisely

Produce
- Manufactured sand

Challenges related to the possibilities:

- The market for manufactured sand
- Winter time with freezing, material, products and processing equipment
- Find production equipment that manage the product requirements, moisture content, wearing of the material etc.
- Integrate additional process in a running plant
- Logistic: Additional gradings at stock
- Dust problems?
Thank you!
Welcome to CDE Global.

CDE – Washing Manufactured Sands

Stavanger 2014
Washed M-Sand: A Realistic Alternative to Natural Sand

Washing Crushed Sands, Why?

- Reduced availability of Natural Sand
- Potential Tax of Natural Sand
- Turn a Waste product into €’s and develop a new revenue stream
- Lack of space to store waste crushed fines
CDE have been washing Crushed Sands across the world for many years

- Bespoke Solution for every Application
- Different Feed Materials sizes and types
- Different End Products Required
- Various capacities
Why Wash?

Before

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Grams Retained</th>
<th>% Retained</th>
<th>Percentage Passing Test Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.000</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3.360</td>
<td>10</td>
<td>1</td>
<td>99</td>
</tr>
<tr>
<td>2.360</td>
<td>47</td>
<td>7</td>
<td>92</td>
</tr>
<tr>
<td>1.180</td>
<td>193</td>
<td>28</td>
<td>64</td>
</tr>
<tr>
<td>0.600</td>
<td>193</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>0.300</td>
<td>124</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>0.212</td>
<td>35</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>0.150</td>
<td>25</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>0.063</td>
<td>44</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>pan</td>
<td>24</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>695</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Evowash Sand Plant

- Removes 0.063mm from raw material
- 30tph – 250tph on a single unit
- De-waters Washed Sand to typically 12-15% moisture content
Various Type of Applications
How to Wash M-Sands: M2500

M2500, M3500, M4500

Feeding  Screening  Sand Washing  Stockpiling
Filter Press

Crushed Granite - Russia
Wet or Dry

Sirocco Air Classifiers

Manufactured Sand - Workshop

Stavanger, Norway, October 20th and 21th 2014
No water required

Ideal for dry loose materials

Best results with dry feed; moisture content should be <2%

Large model range available...

7 models from 50tph to 800tph capacity
How does it work?

Dry or Wet Processing?

- Both Technologies are Viable Solutions
- Wet Processing Yields Cleaner sand and with no loss of ‘fine sand’
- Dry Processing requires no water but demands consistently low moisture content
- Only Wet processing can be used for the processing of ‘existing stockpiles’
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mail: eheron@cdeglobal.com
Web: www.cdeglobal.com
Reidar, Halvard, Egil og Harald Velde

Stavanger, Norway, October 20th and 21th 2014
Enthusiasme

Råstoff
Betongverk

Gjenvinning
Nytt gjenvinningsanlegg
• Kapasitet: 300 tonn pr time
• Gjenvinningsgrad: 70-80%
Utfordringen:
Verdikjede

Transport

Tilslag betong
Tilslag asfalt
Entreprenørvarer
Pumping
Gulvlegging
Sliping
Asfaltering
Fresing

GENVINNING

Nytt tilslag

Retur transport

Miljø
Læring
Verdiskapning

Miljøvennlig

Manufactured Sand - Workshop

Stavanger, Norway, October 20th and 21th 2014
Frømtidsrettet

– Vi bryr oss
Concrete Mix Design with Industrial fillers
- a new approach

Sverre Smeplass, Skanska Teknikk
Oliver Skjølsvik, Skanska Teknikk
Hernan Mujica, Velde

Manufactured sand, seminar, Stavanger 2014-10-21

The Particle - Matrix model (PM)

- The matrix phase
  - Water and chemical additives
  - Cement and pozzolanes
  - Aggregate filler (< 0.125mm)

- The particle phase
  - Aggregate particles > 0.125 mm
The Particle - Matrix model (PM)

The volume ratio matrix / particles

Properties of the particle phase

Matrix rheology

Workability

Matrix properties

Kalkmel

v/p = 0,27
Matrix properties

The FlowCyl test determines the Flow Resistance, $\lambda_Q$, of the matrix

Flow resistance of the concrete

<table>
<thead>
<tr>
<th>Concrete type</th>
<th>Vibrated</th>
<th>SCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>B30 M60 (housing)</td>
<td>0.20-0.40</td>
<td>0.35-0.55</td>
</tr>
<tr>
<td>B45 M40 (civil)</td>
<td>0.40-0.55</td>
<td>0.50-0.65</td>
</tr>
</tbody>
</table>
Matrix volume vs. workability

COIN / Velde test parameters

- **Primary**
  - filler grading
  - filler dosage

- **Secondary**
  - w/c – ratio
  - cement type
  - dosage of superplasticizer
  - type of superplasticizer
**Filler grading**

<table>
<thead>
<tr>
<th>Combinations</th>
<th>Fine filler</th>
<th>Medium filler</th>
<th>Course filler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine combination</td>
<td>60%</td>
<td>40%</td>
<td>0%</td>
</tr>
<tr>
<td>Long combination</td>
<td>40%</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Coarse combination</td>
<td>0%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Reference grading</td>
<td>10%</td>
<td>50%</td>
<td>40%</td>
</tr>
</tbody>
</table>

A total of 52 matrix mixes, all performed at the Velde concrete lab.
Effect of filler grading and dosage (w/c = 0.59)

Effect of filler grading and dosage (w/c = 0.39)
Effect of filler grading and dosage (w/c = 0.59 and 0.39)

\[ y = 0.0241x + 0.1921 \quad R^2 = 0.9751 \]

\[ y = 0.0085x + 0.1318 \quad R^2 = 0.9100 \]

Effect of filler specific surface (w/c = 0.59 and 0.39)

\[ y = 0.0241x + 0.1921 \quad R^2 = 0.9751 \]

\[ y = 0.0085x + 0.1318 \quad R^2 = 0.9100 \]
Summary and conclusions

- Extremely consistent results
- The filler composition can be used to modify or control the concrete workability at the batching plant
- The specific surface of the filler seems to be a single factor governing the filler effect on matrix viscosity
Sustainable Production of fine grained Products from Rock Materials
Rebecka Stomvall
AIM

Sustainable supply of Rock Products

Improved Quality by man-made materials

Replace natural resources and secure the Environmental goals No 9 and 15

Demonstrate the Possibilities
In the whole contry.
Test Equipment on a road show

24 Project Partners

[Logos and names of project partners]

Stavanger, Norway, October 20th and 21th 2014
Transported on two jumbotrailers
Road show through Sweden

- The Equipment has been on tour for 49 weeks
- It has been demonstrated in 12 different Quarries
- In total the Equipment was transported over 4000 km
Many people involved

- The Equipment has been operated by two persons from Chalmers Technical University every week for 42 weeks.
- In total 41 different persons worked with the Equipment.
  - 17 from Chalmers
  - 24 from participating companies.

Unique Test

- 27 different rock materials have been treated.
  - 21 of them within the project.
- In each Quarry at least 10 different test setups were made and at least 60 specimens were sent for analysis.
X – Täkt vars material krossats i testläggningen

LKAB Kiruna
Fantastisk support från verkstadsduken!

Skanska Luleå
Mest bemanning som hjälpte till

Swedrock Umeå
Skickligaste hjullastarföraren

Jehander Gävle
Jättebra samarbete mellan täkterna

Zinkgruvan
Väldigt professionella med bra resurser.

Nordbalk Forsby
Det vackraste täkten!

Den vackraste täkten!

NCC Uddevalla
Läste det mesta, inklusive översvämningar!

NCC Jönköping
Otroligt positiva hela vägen!

Skanska Borlänge
Kunniga problemlöstare

SMA Mineral Filipstad
Trevligaste medarbetarna

Omya Sala
Anläggningen fick stö på asfalt och kopplas in med en 200 m lång strömsladd!

LKAB Kiruna
Fantastisk support från verkstadsspecialisterna!

The set up of the Equipment

Manufactured Sand - Workshop
VSI Crusher
Rotor speed varied between 58 and 79 m/s

<table>
<thead>
<tr>
<th>Void Volume [%]</th>
<th>1-2</th>
<th>0.5-1</th>
<th>250-500</th>
<th>125-250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void Volume [1-2]</td>
<td>V3 V4</td>
<td>V5 V6</td>
<td>V7 V8</td>
<td>V9 V10</td>
</tr>
<tr>
<td>Void Volume [0.5-1]</td>
<td>V9 V12</td>
<td>K3 K4</td>
<td>K6 K7</td>
<td>K8 K9</td>
</tr>
<tr>
<td>Void Volume [250-500]</td>
<td>V7_2 V11</td>
<td>K12 K13</td>
<td>K14 K15</td>
<td>K16 K17</td>
</tr>
<tr>
<td>Void Volume [125-250]</td>
<td>V12 V7_2</td>
<td>K18 K19</td>
<td>K20 K21</td>
<td>K22 K23</td>
</tr>
</tbody>
</table>

Manufactured Sand - Workshop
Stavanger, Norway, October 20th and 21th 2014
Air Classifier
Cut at 63 μm

Effect on the particle size distribution curve

Manufactured Sand - Workshop

Stavanger, Norway, October 20th and 21th 2014
Soil production

• Pot tests
• Full scale tests in Malmö
Study of Mortar screed

- Tests in the Lab have been made with mortar screeds containing
  - Three references with natural sand
  - Four different crusched fine aggregates treated with different rotor speeds in the VSI.
Test of spread

- Målvärde 240-250 mm. Efter 20 min får det inte minska mer än 10 mm
- Utflyt okej för alla prover med ett undantag

Calculated pump velocity

- Target 10 ton/h
- Two of the crushed fine aggregates reached the target.
Strength

- Target in compressive strength 25 MPa
- Small differences in compressive and flexural strength between manufactured and natural fine sand.

Playground sand
Playground sand

- Device released from 3 resp. 2 m
- The Retardation is measured
- Maximum value after 3 drops gives the HIC-value.

![Graph showing HIC-values for 2 m and 3 m drops](image)
Concrete
Spread with minislump cone
The bigger spread the better. Same recipe as for rheological tests (0-0.125 mm)
V= Air classified, K= VSI crushed

Rheology for micro mortar
Recepy: Cement 1000g, water 450 g.
Filler addition is 40% by volume of the Cement.
V= Air classified, K= VSI crushed
Unique test – now data are calculated and results summarized

What is the potential?

Good prospects to replace the natural sand
Methods for characterization of crushed filler properties and principles of proportioning concrete

Importance of properties of fines
Importance of properties of fines

SCC | w/c=0.5 | D_{max}=16 mm
f.vol. = 3.3% => 57 kg/m³

The role of filler & matrix viscosity

Low viscosity matrix

High viscosity matrix
Characterisation of fines – PSD & specific surface

3D mathematical analysis of particle shape using X-ray CT and spherical harmonics (6.3 mm to 12.7 mm aggregate particles):

Characterisation of fines – shape

Static air-classification – opportunities

Stavanger, Norway, October 20th and 21th 2014
Static air-classification – opportunities

Some conceptual rheology results
How to determine the influence of aggregate fillers on the yield stress and plastic viscosity of micro mortar

Hans-Erik Gram

Stavanger 21 October 2014

Content

- Definition of filler < 0.063 mm (<0.125 mm)
- Differences between natural and crushed fillers
- Test methods
- Effect of superplasticizers
- Water absorption of fillers?
Natural versus crushed fine aggregates

0 0.063 0.125 0.25 0.5 1 2 4 5.6 8 11.2 16 18

0 10 20 30 40 50 60 70 80 90 100

crushed
natural

Manufactured Sand - Workshop

3.4 % versus 17%
Dry versus Wet sieving

Dry versus Wet sieving

Mixture of natural aggregate fillers and cement

30 kg

0,125 mm

300 kg

Cement grains < 0,063 mm

0,032 mm

0,014 mm

0,020 mm

0,014 mm

0,020 mm
Mixture of crushed aggregate fillers and cement

- 150 kg
- 0,125 mm
- 0,020 mm
- 0,014 mm
- 300 kg
- Cement grains < 0,063 mm
- 0,032 mm
- 0,020 mm
- 0,014 mm

Test methods for particles < 0,125 mm Wet methods
- Laser Sieving
- BET surface
- Sand Equalent SS-EN 933-8:2012
- Mehtylene Blue Test
- Viskometer/Rheometer tests
- Flow time in Cone tests like FlowCyl, other cones etc
- Minislump cones and Hägermann cone
- L-box for micromortar
- Puntke –test
- Sausage-test
How is the filler to be studied?

With or without Cement???

The sausage method – needs 500 g of powder

Water added until sausages are formed. The saturation point is then calculated.

Source: Stephane Broccas
The Puntke - method

Vibrating table

Container and scale

The Puntke test – adding water and mixing
The Puntke test – The surface shall be blank when sample is vibrated – then the sample is placed on the scale

The saturation point is then calculated

Plastic viscosity versus Puntke absorption value

Björn Lagerblad, CBI
The Rheometer

The camera registrates the flow and the time to reach a specified distance is determined.

Alternatives to the Rheometer – The L-box for micro mortar

Developed by Annika Gram
Operation of the L-box

The flow distance is measured – correlates with the yield stress

The micro mortar is also tested in the Rheometer to control the result
The time it takes for the mortar to reach a specified distance is used to calculate the **plastic viscosity**

Another alternative to the Rheometer is the flow cone and micro mortar cone

The sample is prepared
And the place on a scale
The flow time is measured – correlates to the plastic viscosity

The spread is determined and it correlates with the yield stress
Water absorption of fine aggregates

According to the standard fines shall be removed when determining the water absorption.

In manufactured sand a substantial part is filler

The filler does increase the water demand of the concrete. Is some part of this water absorbed???
The future for sand and gravel?

"Sand & gravel"
Find the red circles (sand and gravel future resources)

Production of sand and gravel 2013
Source NGU
NGU report 2012 062 reserves and resources, sand and gravel table five million tons according to (FRB) JORC code

<table>
<thead>
<tr>
<th>Reserves</th>
<th>probable</th>
<th>Proved</th>
</tr>
</thead>
<tbody>
<tr>
<td>289</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>Indicated measured</td>
<td></td>
</tr>
<tr>
<td>452</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>741</td>
<td>92</td>
</tr>
</tbody>
</table>

Use of sand and gravel in the future

- Easy mathematics if present depletion continues. 140 million tons lost in next ten years and 280 million in the next twenty years.
- But we might have reserves and resources in the range of 850-900 million tons
  - Maybe enough for 60 yrs.
- Or do we?
- I suggest, that within the present regime of planning, cultural heritage and landscape protection the remaining accessible reserves and resources lies between 1/3 to 1/2 of the the maximum of 900 million tons.
  - Maybe enough for another 20-30 yrs. Without taking in to account proximity to marked etc.
Limiting faktors sand and gravel Resources

- Our ancestors liked living on and burying their dead in sand and gravel.
  - Large part of the remaining resources sterilized by cultural heritage
- Cheap and good ground for buildings and structures
  - Norway's main airport and the airport at Geiteryggen.
- Quaternary geology
  - Resources sterilized for landscape purposes
- We love to stroll in quaternary landscapes
  - Important leisure areas in several municipalities
- Gravel and sand = water
  - Important groundwater resources may sterilize resources
- A large part of our remaining resources sterilized by these factors

Sand and gravel in Ryfylke (from regional plan)
grade of sterilizing from left to right

![Bar chart showing sterilization grades](chart.png)
Regional plans for sand and gravel

Why make a regional plan for sand and gravel?

- Gives us better picture of the future situation for sand and gravel
- Will help us plan for future sand and gravel pits
  - Better understanding of future supply and demand
  - Common guidelines for municipalities
- Securing access to building materials in a sustainable perspective
  - Prioritize between different land use issues
  - Secure important resources against alternative use

Regional plan Jæren

Fylkesdelplan for byggeråstoff på Jæren
Vedtatt plan 12. desember 2006
Regional plan Jæren main features

- A plan for Jæren future needs for building materials?
  - Gives an opening for future expansion of existing quarries
  - Planning for new sites
  - Explore the need for importing materials. Especially from Ryfylke
  - Extract remaining resources in a sustainable manner.

- The conclusion is that the region are facing a future shortage of sand and gravel.
Regional plan Ryfylke

Important issues
- Local communities
- Outdoor activities
- Cultural heritage
- Sites of importance
- Landscape
Important issues
- Agriculture
- Biodiversity
- Protected waterways
- Groundwater

Issues regarding the resources
- Inherent quality
- Relative importance of the resource (size)
- Location
- Marked
Conclusion regional plan Ryfylke

- Remaining resources in the region for another 10-12 yrs.
  - Provided that resources in category 0 and 1 is developed

- Resources in category 2 and 3 might give another 20 yrs.

- There is no other way of replacing these resources than by manufactured sand.

Coin

The responsibility of the industry and the authorities

- Secure optimal utilization of the resources
- Correct quality for correct use
- Manufactured sand replacing natural sand and gravel. Gradually.
- Increased Recycling concrete and asphalt
- Increased R&D regarding production and use of machined sand
- Change of attitude and increased R&D also in the end user segment
- We have to accept increased prizes for some products
Some proposals

- County plans for building materials in every county and compliance from the municipalities
- Increased focus on geology in the overall planning. Resource geologist in each county.
- Increased focus on resource issues from central government.

Thank you
Current and future consumption and supply of building materials in Norway

Rolv Dahl, Geological Survey of Norway
COIN-seminar, Stavanger October 21st 2014

Outline

- International perspective
- Key figures from Norway
- Predictions
- Some words on land-use planning
Global perspectives

- Consumption of cement in the USA totaled about 4.56 Gt during the entire twentieth century –
- while China emplaced more cement (4.9 Gt) in new construction in just three years between 2008 and 2010,
- and in three years between 2009 and 2011 it used even more, 5.5t.
Norwegian construction materials industry in 2013

- Total turnover: aggregates: 4400 Mill NOK sand 925 Mill NOK.
- 66 million tonnes hard rock.
- 14 million tonnes sand and gravel.
- Export sales: NOK 1100 Mill NOK.
- 21 million tonnes exported.
- 531 aggregate quarries, 461 gravel pits in operation, ranging from small enterprises to international companies.
Use of Norwegian construction materials

<table>
<thead>
<tr>
<th>Type/ use</th>
<th>Roads</th>
<th>Asphalt</th>
<th>Concrete</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/gravel</td>
<td>18.5 %</td>
<td>13.6 %</td>
<td>48.4 %</td>
<td>19.1 %</td>
</tr>
<tr>
<td>Hard-rock aggregates</td>
<td><strong>44.6 %</strong></td>
<td>11.3 %</td>
<td>8.7 %</td>
<td>35.1 %</td>
</tr>
</tbody>
</table>
We export aggregates...

...a slight increase in the domestic consumption ...

Annual consumption per capita in Norway ~ 12 tonnes

Transportation costs
...particularly around cities...
Annual consumption of 7.2 mill tonnes of gravel and hard-rock aggregates in Oslo/Akershus

...and it is transported far.

- Sand was in average transported 21 km by car, 147 km by boat
- Hard-rock aggregates was in average transported 17 km by car, 135 km by boat
- The transportation causes an annual CO₂ emission of 140,000 tonnes.
Shift towards hard-rock aggregates

<table>
<thead>
<tr>
<th>Type/production</th>
<th>2002 Ktonnes</th>
<th>2008 Ktonnes</th>
<th>2013 Ktonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard-rock aggregates</td>
<td>35000</td>
<td>54000</td>
<td>66000</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>15000</td>
<td>15000</td>
<td>14000</td>
</tr>
</tbody>
</table>

The resource/production ratio of natural sands is low in parts of Norway
Predictions

- No decrease in demand
- Decrease in offer?
- Fewer, bigger quarries
- Shift towards manufactured sand
- Recycling?
- Landfill?
- Harbour terminals for megaquarries?
- Underground quarrying?
- Need for better material characterization

You are all invited!
A perfect quarry...

- ... exploits rocks with excellent properties
- ... has a high reserves/production ratio
- ... has no problems with noise and dust

- ... has no conflict with nature diversity, cultural heritage or other land use
- ... has no conflict with neighbours
- ... is situated in the middle of the city

Competing land use interests

- NIMBY
- Urbanisation
- Conservation acts
- Groundwater
- Sustainable management requires balanced land use planning.
- Land use planning requires unbiased information on resources.
Natural construction materials

Deposits of national and regional significance

80 of national significance
90 of regional significance

Annual review

Valorisation of deposits of sand, gravel and hard-rock aggregates

• Significance
  • National
  • Regional
  • Local
  • Little significance
Thank you for your attention
How to secure Norway's aggregate supply?

10 tons of aggregates pr. person pr. year
Mineral Strategy

- Presented by the Ministry of Trade and Industry in March 2013
- Shows great expectations to the Norwegian mineral industry in the years to come
- High hopes for increased sustainability and environmental standards
- The new government continues the work of its predecessors

The mineral industry is considered a key policy area

- Parliamentary Elections one year ago won by liberal/conservative coalition
- The Government will pursue an active policy for the High North
- Seeks to intensify the exploration of mineral deposits in the Northern counties
- Very positive signals in the new government’s political platform was presented on October 7th 2013
  - The mineral industry is considered to be a key policy area
Future supplies in the hands of local governments

Cooperation, communication, knowledge

Simple tool for difficult task: A movie to open peoples eyes
A man with no colleges

Region Geologist in Buskerud, Telemark and Vestfold, Sven Dahlgren

State budget 2015

- Presented on October 8, 2014
- This government’s first original budget
- Substantial increase on infrastructure development means increased need of aggregates
### Challenges

- Need to increase knowledge about geological resources within both national, regional and local governments
- Need for more predictable and less time consuming planning processes
- Need for enhanced communication between national and local governments in order to implement means to reach goals set out in the Mineral Strategy

### Possibilities

- The mineral industry is pointed out as a key policy area by the new government
- The state budget includes NOK 55 billion to infrastructure – very positive for the aggregate industry
- The new government are well aware of the challenges with unpredictable planning processes

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**Thank you for your time**

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+47 412 18 190
**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.

**COIN – Concrete Innovation Center** is a Center for Research based Innovation (CRI) initiated by the Research Council of Norway. The vision of COIN is creation of more attractive concrete buildings and constructions. The primary goal is to fulfill this vision by bringing the development a major leap forward by long-term research in close alliances with the industry regarding advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.