Manufactured Sand For a Low Carbon Era

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Introduction

- Current practice in UK
  - Blend crusher dust with natural sand.
    - Excess of sub-63 micron particles in dust
    - Flaky and very angular
    - Lack of 0.3 to 1 mm particles
Aims

- Replace natural sand and sand blends in concrete with 100% manufactured sand
- Investigate fine aggregate test applicability to manufactured sands
Sand Manufacturing process

- Integrated in the quarry crusher system
- Dry process – the product is not washed
- Water added to the final product to avoid segregation (3%)
- “Skimmer” particles added back in the produced sand, therefore creating different gradings (-A,-B,-C,-D) with different sub 63 micron content and increasing yield
Materials

- CEM I 52.5 N
- Crushed limestone 4/20 mm (CA)
- Sea dredged natural sand control (N)
- Crusher dusts (..-FEED)
- Manufactured sands from crusher dusts with at least 4 gradings for each quarry
  - Basalt (B)
  - Granite (G)
  - Limestone (L)
  - Sandstone (Gritstone) (S)
- Mid range plasticizer WRDA 90
Characterisation tests

**Fine Aggregate**
- New Zealand Flow Cone (NZS 3111-1986)
- Particle size distribution (BS EN 933-1)
- Water absorption (BS EN 1097-6)
- Methylene Blue Value (BS EN 933-9)
- GMBV (Grace Rapid Clay test)
- Sand Equivalent (BS EN 933-8 )

**Fresh Concrete**
- Observations from mixing (finishability, ease of placement)
- Plastic Density
- Slump
- Air Entrainment

**Hardened Concrete**
- Flexural strength –28 days
- Compressive strength –1 day
- –7 days
- –28 days
Concrete mixes

- Two stages
  - Stage 1: without plasticizer, aiming for S2 slump, fixed w/c ratio for particular quarry sands which provides S2 slump.
  - Stage 2: Varying plasticizer dosage to achieve S2 slump, fixed w/c ratio at 0.55 for all sands.

<table>
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<tr>
<th>Cement</th>
<th>FA</th>
<th>CA</th>
<th>Water</th>
<th>Plasticizer</th>
</tr>
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<td>350</td>
<td>753</td>
<td>1040</td>
<td>varies</td>
<td></td>
</tr>
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- Accounted for absorption capacity and water content of aggregates and admixtures
Results – Fine aggregate tests

Crusher dust Feed (0-4)  Manufactured sand (0-4)  Sea dredged sand (0-4)
Results – Particle Size Distribution

- **Basalt sand grading**
  - B-FEED
  - B-A
  - B-B
  - B-C
  - B-D
  - N

- **Sandstone sand grading**
  - S-FEED
  - S-A
  - S-B
  - S-C
  - S-D

- **Granite sand grading**
  - G-FEED
  - G-A
  - G-B
  - G-C
  - G-D
  - G-E

- **Limestone sand grading**
  - L-FEED
  - L-A
  - L-B
  - L-C
  - L-D
Results – New Zealand Flow Cone

- Simple indirect test indicating shape, grading and surface texture

![Diagram showing flow cone test results for different types of sand and their voids percentage]
Results – MBV, GMBV, SE

- Natural sand
- Granite
- Basalt
- Limestone
- Sandstone

Methylene Blue Value, g/g of sand

Samples:
- N
- G-EEED
- G-A
- G-B
- G-C
- G-D
- G-E
- B-EEED
- B-A
- B-B
- B-C
- B-D
- L-EEED
- L-A
- L-B
- L-C
- L-D
- S-EEED
- S-A
- S-B
- S-C
- S-D

- Sand Equivalent

Legend:
- Methylene Blue Value
- Grace Methylene Blue Value
- Sand Equivalent Value
Results – MBV, GMBV

- Comparing two methods for MBV testing

\[ y = 1.1618x + 0.0741 \]

\[ R^2 = 0.98991 \]
Results - Concrete, Stage 1

Compressive, flexural strength and slump

Slump against percentage of fines of FA

Concrete mixes

1 day compressive strength
7 day compressive strength
28 day compressive strength
28 day flexural strength
Slump, mm

Compressive, flexural strength, N/mm²

N slump

Natural sand w/c 0.48
Granite w/c 0.58
Basalt w/c 0.67
Limestone w/c 0.55
Sandstone w/c 0.67

Slump, mm

% sub-63 micron particles of FA

Granite sands w/c 0.58
Basalt sands w/c 0.67
Sanstone sands w/c 0.67
Limestone sands w/c 0.55
Results – Concrete, Stage 2

Compressive, flexural strength and slump for w/c 0.55

- Natural sand
- Granite
- Basalt
- Limestone

Compressive strength:
- 1 day
- 7 day
- 28 day

Flexural strength:
- 28 day

Slump, mm

Materials:
- Granite
- Basalt
- Limestone
- Natural sand
Conclusions

- It has been demonstrated that viable concretes can be produced using 100% manufactured sands.
- Good strength and workability can be achieved regardless of rock mineralogy by appropriate manipulation of w/c ratio and particle size distribution.
- Caution must be exercised when using manufactured sands which contain clays.
- MBV tests are good indicators of the presence of clays.
- Sustainability and environmental benefits.
Thank you for your attention!
Any questions?

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