SEM Images of Ottawa F-65 Sand Grains, Photo Album

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Imaging procedure
**Imaging procedure – sample preparation**

Samples were prepared as follows:

1. Samples of the original sands were obtained from the batched delivered at the University of California Davis Center for Geotechnical Modelling (UC Davis CGM) on May 2014. After testing, crushed soil samples were obtained from brushing the material from the one-dimensional compression test mold.

2. Air dried soil samples were mixed thoroughly to obtain a uniform sample.

3. Black carbon double sided tape was placed on the SEM aluminum pedestal with white protective layer on.
Imaging procedure – sample preparation

Samples were prepared as follows:

4. A triangular segment of the carbon tape and the white protective layer were removed to expose aluminum. This was used as a location reference during imaging.

5. The white protective layer was cut and removed to expose small sections of black sticking surface.

6. Small but representative soil samples were placed on the adhesive surface (Figure 1).

7. The pedestal was tapped to remove weakly attached particles.
Imaging procedure – sample preparation

Samples were prepared as follows:

8. Further sections of the white protective layer were cut and removed for subsequent samples.

9. Additional samples were placed carefully in pre-determined segments of the pedestal being sure to remember their location.

10. After applying all soil samples, the pedestal was stored inside a glass beaker with a foil cover and was placed in a drying oven with temperature of 110° C for 2 days before imaging. This process was performed to remove excess of moisture which could distort the SEM images.
Imaging procedure – sample preparation

Figure 1. Pedestal with four samples ready for SEM imaging
Imaging procedure - microscope

- The images were performed using the HITACHI S-4100T Field Emission Scanning Electron Microscope (FE-SEM) with and OXFORD INCA Energy Dispersive X-ray Spectrometer (EDS).

- The HITACHI S-4100T has a Functional resolution – better than 2 nm and a resolution of 132 eV (Hicklin and Liu, 2012).

Figure 2. FE-SEM
Summary
1D-Compression $\sigma'_{v_{\text{max}}} = 30$ MPa

- **Crushed Ottawa F-65 30 MPa loose specimen**
  - 750 μm x 40

- **Original Ottawa sand F-65 750 μm x 40**

- **Crushed Ottawa F-65 30 MPa dense Specimen 750 μm x 40**

- **Original Ottawa sand F-65 200 μm x 150**

- **Crushed Ottawa F-65 30 MPa dense Specimen 200 μm x 150**

- **Original Ottawa sand F-65 100 μm x 300**

- **Crushed Ottawa F-65 30 MPa dense Specimen 100 μm x 300**

- **Crushed Ottawa F-65 30 MPa loose specimen 750 μm x 40**

- **Crushed Ottawa F-65 30 MPa loose specimen 200 μm x 150**

- **Crushed Ottawa F-65 30 MPa loose specimen 100 μm x 300**

Source: Gomez and Parra Bastidas (2016)
$1D$-Compression $\sigma'_{v_{\text{max}}} = 70 \text{ MPa}$

Original Ottawa sand F-65 750 $\mu$m x40

Crushed Ottawa F-65 70 MPa dense specimen 750 $\mu$m x40

Crushed Ottawa F-65 70 MPa dense specimen 750 $\mu$m x40

Crushed Ottawa F-65 70 MPa loose specimen 750 $\mu$m x40

Crushed Ottawa F-65 70 MPa loose specimen 200 $\mu$m x150

Crushed Ottawa F-65 70 MPa loose specimen 200 $\mu$m x150

Crushed Ottawa F-65 70 MPa loose specimen 100 $\mu$m x300

Crushed Ottawa F-65 70 MPa loose specimen 100 $\mu$m x300

Gomez and Parra Bastidas (2016)
$1D$-Compression $\sigma'_{vmax} = 140$ MPa

Gomez and Parra Bastidas (2016)
Particle breakage stages
Particle breakage stages

1. Move
2. Grind their surface
3. Brake off asperities
4. Asperities split
5. Splits theirselves

Nakata et al., 2001
(2) Surface grinding

Original Ottawa sand F-65 200 μm x150

Crushed Ottawa F-65 30 MPa loose specimen 200 μm x150

PB,2016

Crushed Ottawa F-65 30 MPa loose specimen 60 μm x500

Gomez and Parra Bastidas (2016)
(3) Asperities breakage and (4) asperities split

Original Ottawa sand F-65 200 μm x150

Crushed Ottawa F-65 70 MPa loose specimen 150 μm x200

Crushed Ottawa F-65 30 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 30 MPa loose specimen 30 μm x1000

PB, 2016

3/8/2016

Gomez and Parra Bastidas (2016)
(5) Particles and asperities split in the middle

Original Ottawa sand F-65 200 μm x150

Crushed Ottawa F-65 140 MPa dense specimen 15 μm x2000

Crushed Ottawa F-65 140 MPa dense specimen 5 μm x6000

Crushed Ottawa F-65 70 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 70 MPa loose specimen 12 μm x2500

Crushed Ottawa F-65 140 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 140 MPa loose specimen 20 μm x1500

Gomez and Parra Bastidas (2016)
Images on original sand
Images on loose prepared specimens
Loose prepared specimens
1D-Compression $\sigma'_{v_{max}} = 30$ MPa
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens

Crushed Ottawa F-65 30 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 30 MPa loose specimen 200 μm x150

PB,2016

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens

Crushed Ottawa F-65 30 MPa loose specimen 200 μm x150

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Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens

Crushed Ottawa F-65 30 MPa loose specimen 150 μm x200

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Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens
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Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens

Crushed Ottawa F-65 30 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 30 MPa loose specimen 30 μm x1000

Crushed Ottawa F-65 30 MPa loose specimen 12 μm x2500

Gomez and Parra Bastidas (2016)
Loose prepared specimens
1D-Compression $\sigma'_{\text{vmax}} = 70$ MPa
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens

Crushed Ottawa F-65 70 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 70 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 70 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 70 MPa loose specimen 750 μm x40

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens

Crushed Ottawa F-65 70 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 70 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 70 MPa loose specimen 300 μm x100

Crushed Ottawa F-65 70 MPa loose specimen 200 μm x150

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens

Crushed Ottawa F-65 70 MPa loose specimen 200 μm x150

PB,2016

Crushed Ottawa F-65 70 MPa loose specimen 200 μm x150

PB,2016

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens

Crushed Ottawa F-65 70 MPa loose specimen 150 μm x200

Crushed Ottawa F-65 70 MPa loose specimen 100 μm x300

Crushed Ottawa F-65 70 MPa loose specimen 150 μm x200

Crushed Ottawa F-65 70 MPa loose specimen 60 μm x500
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens

Crushed Ottawa F-65 70 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 70 MPa loose specimen 12 μm x2500

Gomez and Parra Bastidas (2016)
Loose prepared specimens

1D-Compression $\sigma'_{v_{\text{max}}}=140$ MPa
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens

Crushed Ottawa F-65 140 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 140 MPa loose specimen 300 μm x100

Crushed Ottawa F-65 140 MPa loose specimen 750 μm x40

Crushed Ottawa F-65 140 MPa loose specimen 300 μm x100

PB, 2016

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Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens

Crushed Ottawa F-65 140 MPa loose specimen 200 μm x150

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Crushed Ottawa F-65 140 MPa loose specimen 150 μm x200

Crushed Ottawa F-65 140 MPa loose specimen 150 μm x200
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens

Crushed Ottawa F-65 140 MPa loose specimen 100 μm x300

Crushed Ottawa F-65 140 MPa loose specimen 60 μm x500

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens

Crushed Ottawa F-65 140 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 140 MPa loose specimen 60 μm x500

Crushed Ottawa F-65 140 MPa loose specimen 20 μm x1500

Gomez and Parra Bastidas (2016)
Images on dense prepared specimens
Dense prepared specimens
1D-Compression $\sigma'_{v_{\text{max}}} = 30 \text{ MPa}$
Ottawa sand F-65 grains post 1D-compression 30 MPa dense specimens

- Crushed Ottawa F-65 30 MPa dense Specimen 750 μm x40
- Crushed Ottawa F-65 30 MPa dense Specimen 500 μm x60
- Crushed Ottawa F-65 30 MPa dense Specimen 200 μm x150
- Crushed Ottawa F-65 30 MPa dense Specimen 100 μm x300
Dense prepared specimens
1D-Compression \( \sigma'_{v_{\text{max}}} = 70 \ \text{MPa} \)
Ottawa sand F-65 grains post 1D-compression 70 MPa dense specimens

Crushed Ottawa F-65 70 MPa dense specimen 750 μm x40

Crushed Ottawa F-65 70 MPa dense specimen 500 μm x60

Crushed Ottawa F-65 70 MPa dense specimen 200 μm x150

Crushed Ottawa F-65 70 MPa dense specimen 100 μm x300
Ottawa sand F-65 grains post 1D-compression 70 MPa dense specimens

Crushed Ottawa F-65 70 MPa dense specimen 50 μm x600

PB.2016
Dense prepared specimens

1D-Compression $\sigma'_{\text{vmax}} = 140 \, \text{MPa}$
Ottawa sand F-65 grains post 1D-compression 140 MPa dense specimens

Crushed Ottawa F-65 140 MPa dense specimen 750 μm x40

Crushed Ottawa F-65 140 MPa dense specimen 19 750 μm x40

Crushed Ottawa F-65 140 MPa dense specimen 20 750 μm x40

Crushed Ottawa F-65 140 MPa dense specimen 21 500 μm x60

3/8/2016

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 140 MPa dense specimens

Crushed Ottawa F-65 140 MPa dense specimen 200 μm x150

Crushed Ottawa F-65 140 MPa dense specimen 100 μm x300

Crushed Ottawa F-65 140 MPa dense specimen 50 μm x600

Crushed Ottawa F-65 140 MPa dense specimen 50 μm x600

Gomez and Parra Bastidas (2016)
Ottawa sand F-65 grains post 1D-compression 140 MPa dense specimens

Crushed Ottawa F-65 140 MPa dense specimen 15 μm x2000

Crushed Ottawa F-65 140 MPa dense specimen 10 μm x3000

Crushed Ottawa F-65 140 MPa dense specimen 5 μm x6000

Gomez and Parra Bastidas (2016)
Questions?
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