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

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  - 1D-Compression σ'_{vmax}=30 MPa
  - 1D-Compression σ'_{vmax}=70 MPa
  - 1D-Compression σ'_{vmax}=140 MPa

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).

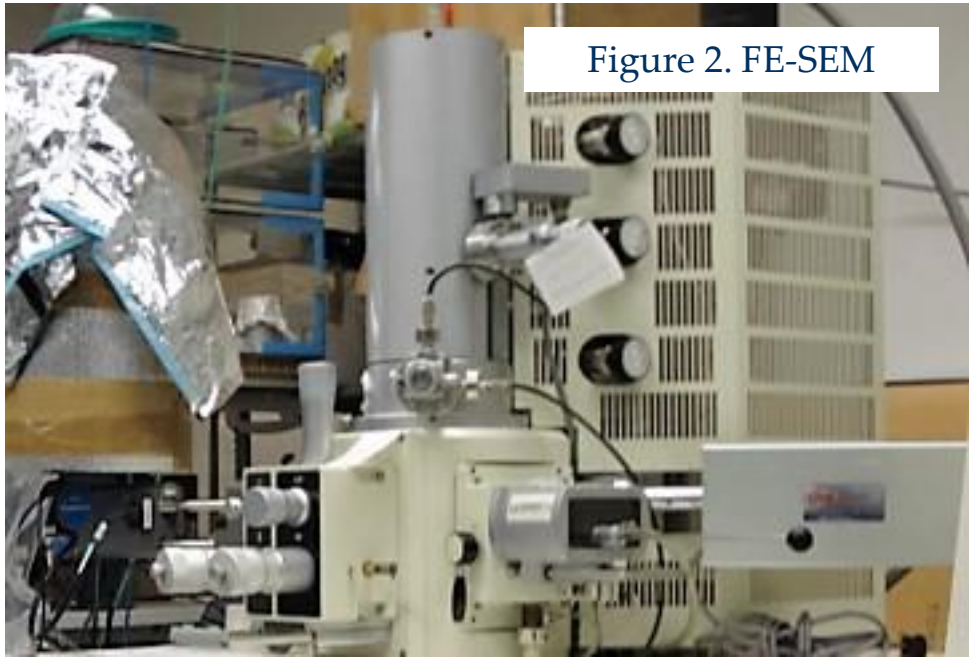
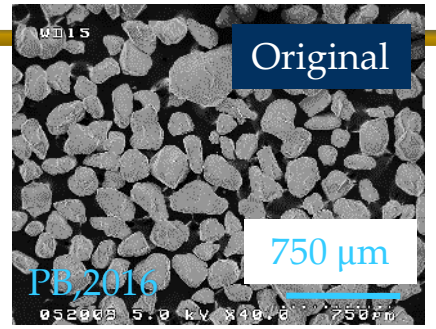


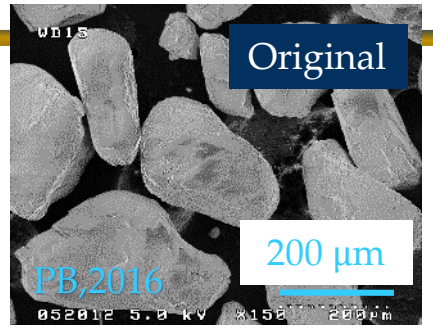
Figure 2. FE-SEM

Summary

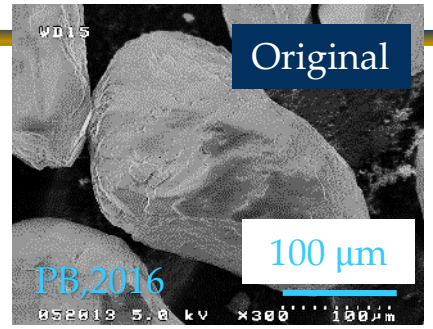
1D-Compression σ'_{vmax}=30 MPa



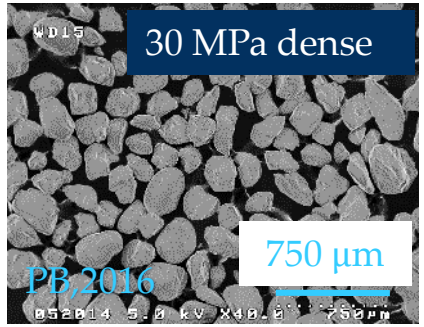
Original Ottawa sand F-65 750 µm x40



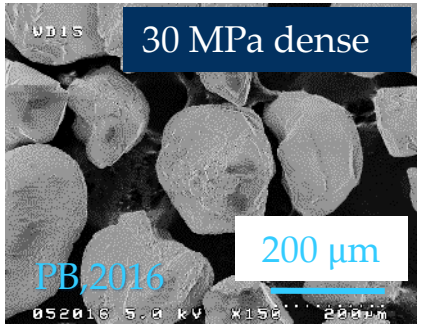
Original Ottawa sand F-65 200 µm x150



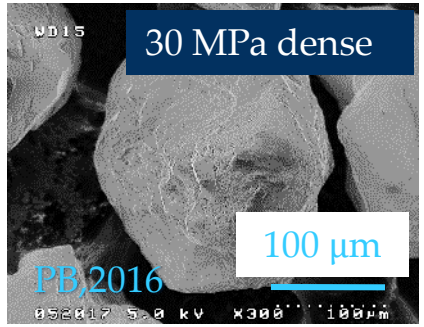
Original Ottawa sand F-65 100 µm x300



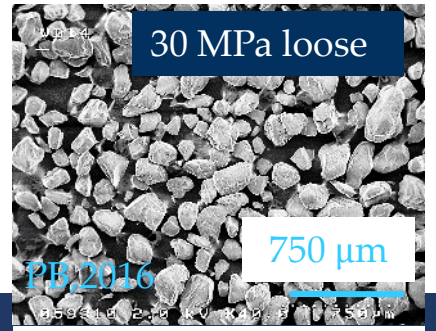
Crushed Ottawa F-65 30 MPa dense Specimen 750 µm x40



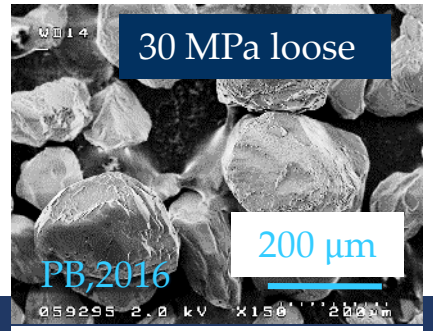
Crushed Ottawa F-65 30 MPa dense Specimen 200 µm x150



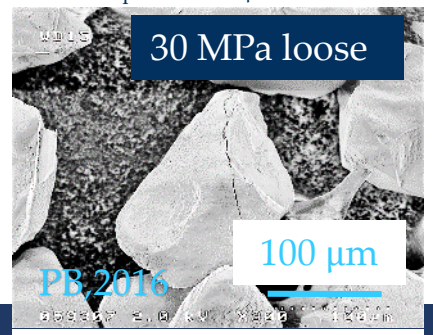
Crushed Ottawa F-65 30 MPa dense Specimen 100 µm x300



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

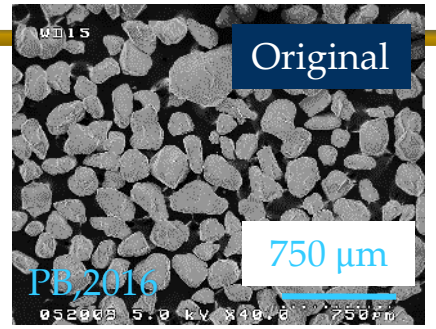


Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150

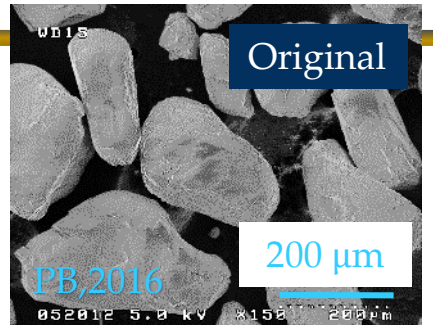


Crushed Ottawa F-65 30 MPa loose specimen 100 µm x300

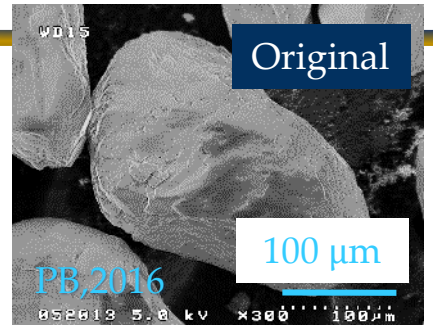
1D-Compression σ'_{vmax}=70 MPa



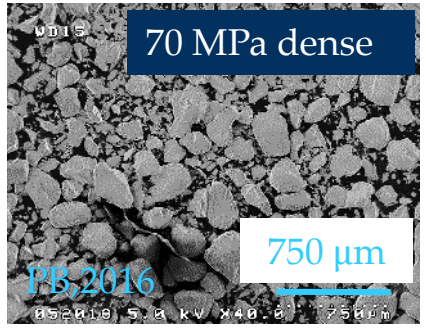
Original Ottawa sand F-65 750 µm x40



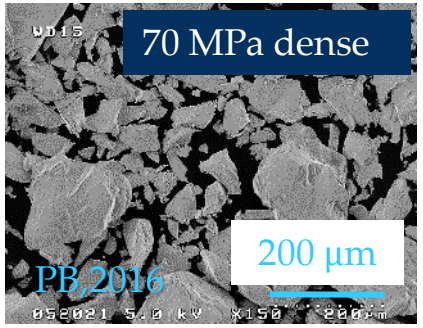
Original Ottawa sand F-65 200 µm x150



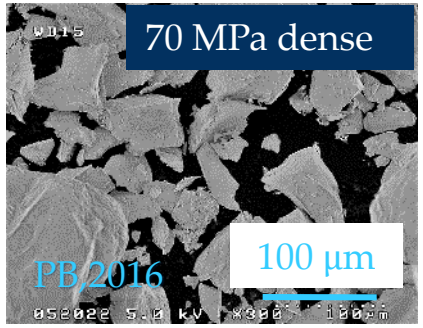
Original Ottawa sand F-65 100 µm x300



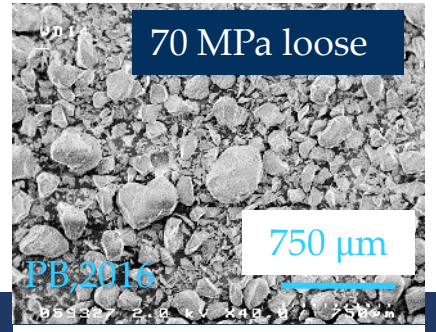
Crushed Ottawa F-65 70 MPa dense specimen 750 µm x40



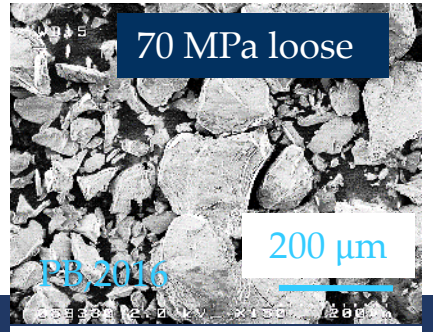
Crushed Ottawa F-65 70 MPa dense specimen 200 µm x150



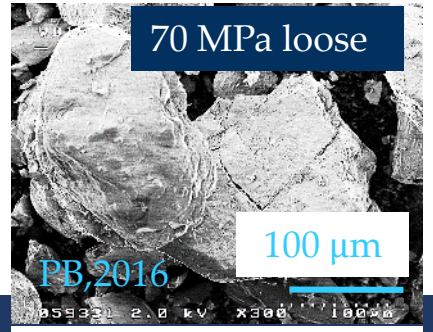
Crushed Ottawa F-65 70 MPa dense specimen 100 µm x300



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

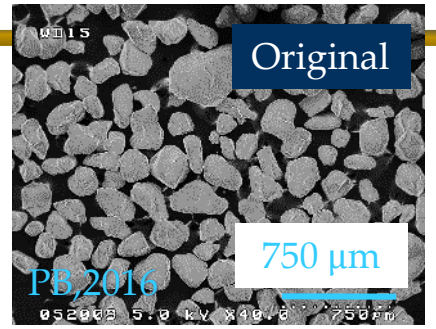


Crushed Ottawa F-65 70 MPa loose specimen 200 µm x150

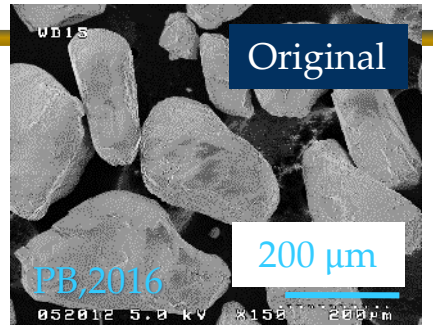


Crushed Ottawa F-65 70 MPa loose specimen 100 µm x300

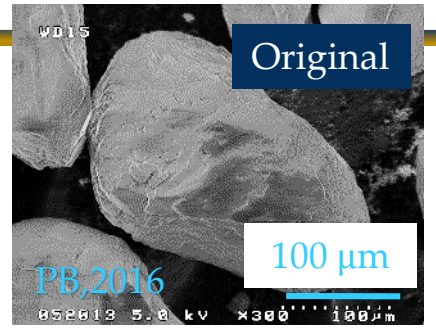
1D-Compression σ'_{vmax}=140 MPa



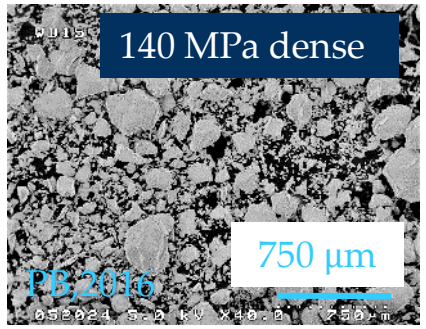
Original Ottawa sand F-65 750 µm x40



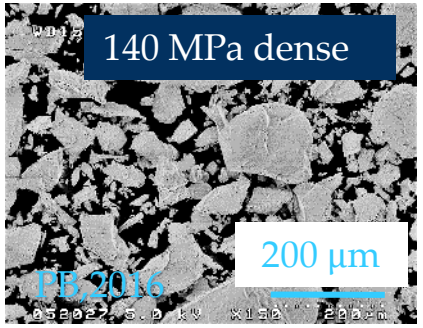
Original Ottawa sand F-65 200 µm x150



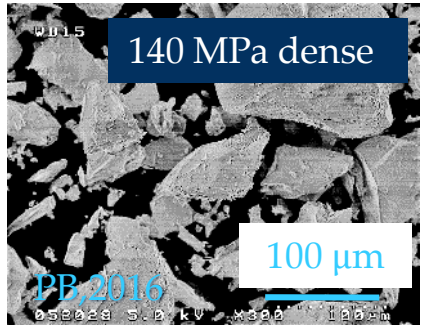
Original Ottawa sand F-65 100 µm x300



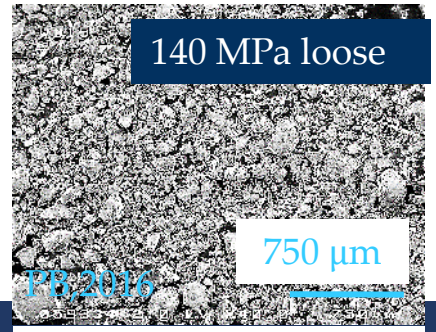
Crushed Ottawa F-65 140 MPa dense specimen 750 µm x40



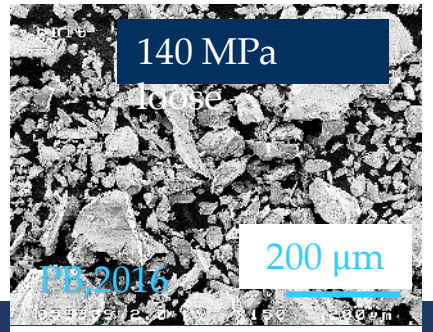
Crushed Ottawa F-65 140 MPa dense specimen 200 µm x150



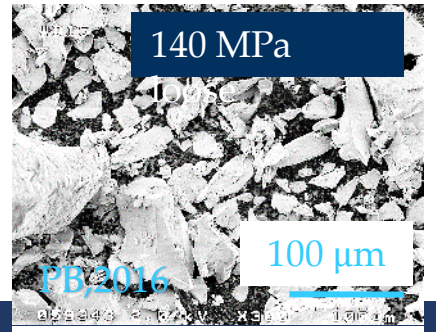
Crushed Ottawa F-65 140 MPa dense specimen 100 µm x300



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



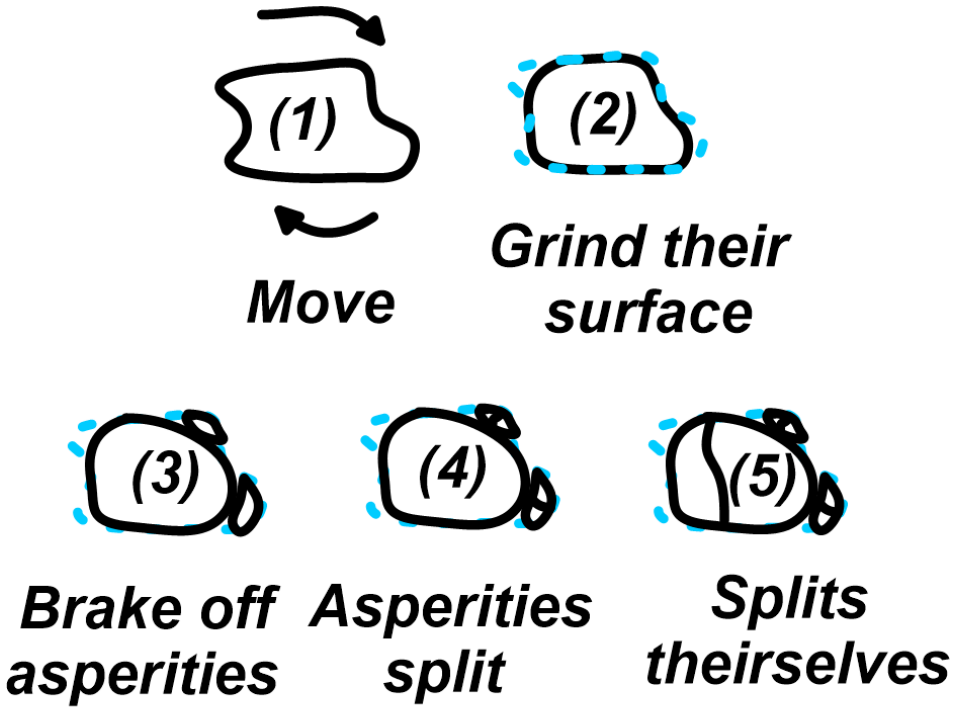
Crushed Ottawa F-65 140 MPa loose specimen 200 µm x150



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

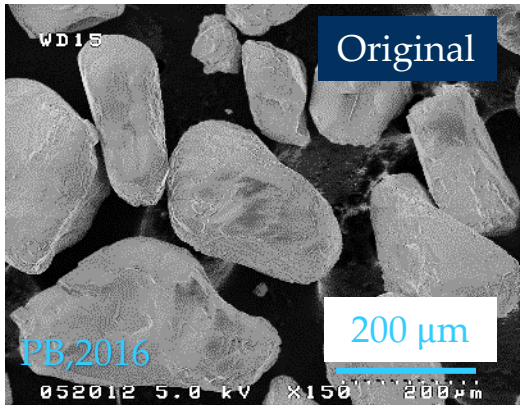
Particle breakage stages

Particle breakage stages

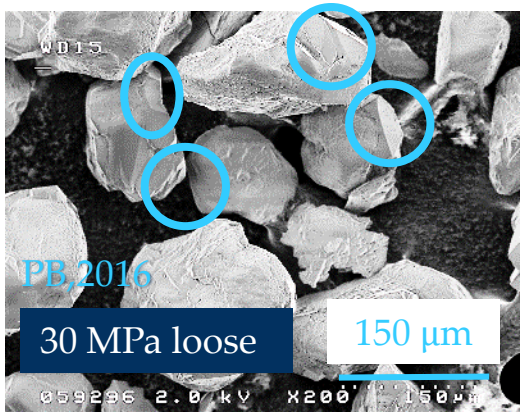


Nakata et al., 2001

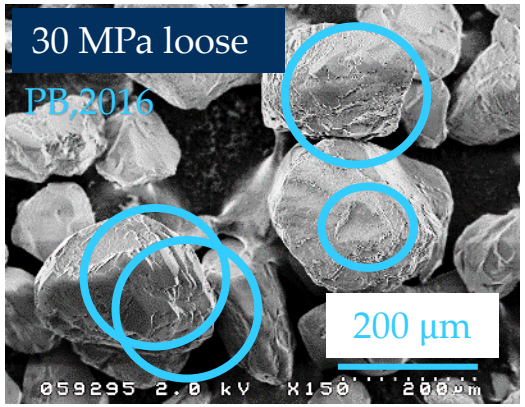
(2) Surface grinding ??



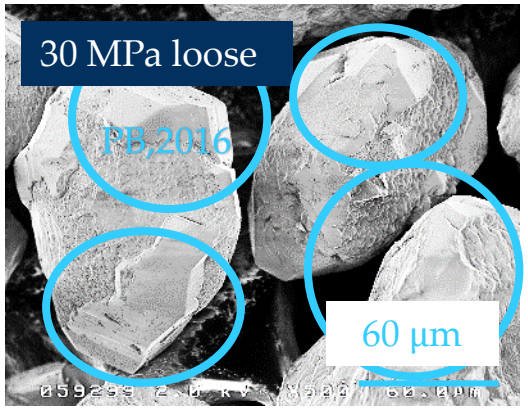
Original Ottawa sand F-65 200 µm x150



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

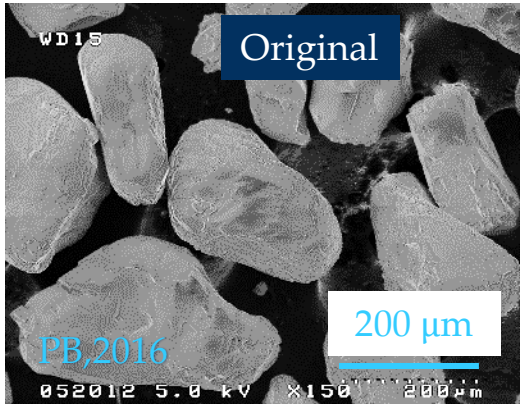


Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150

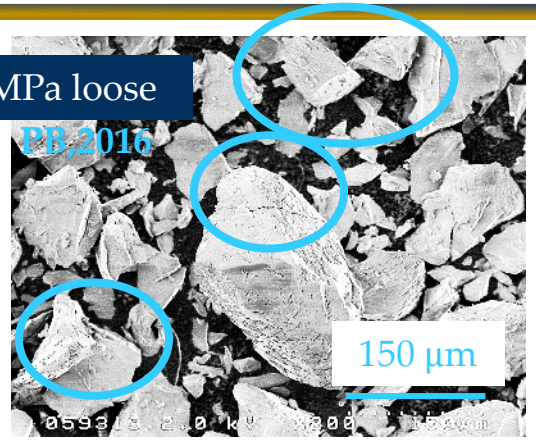


Crushed Ottawa F-65 30 MPa loose specimen 60 µm x500

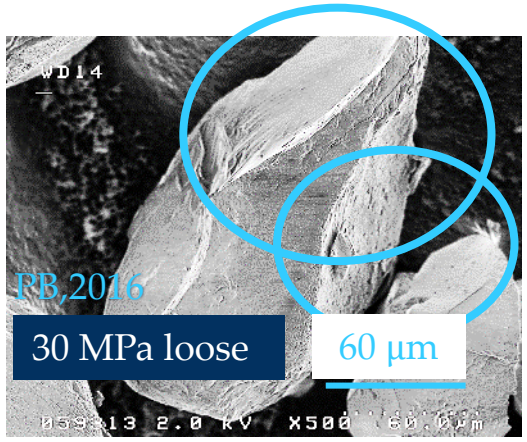
(3) Asperities breakage and (4) asperities split



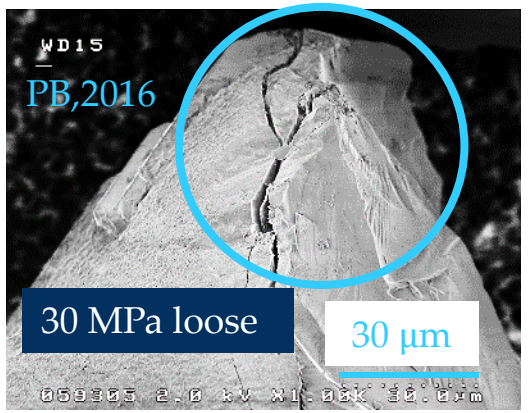
Original Ottawa sand F-65 200 µm x150



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

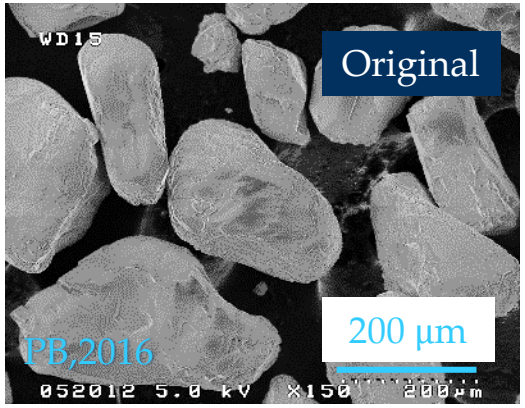


Crushed Ottawa F-65 30 MPa loose specimen 60 µm x500

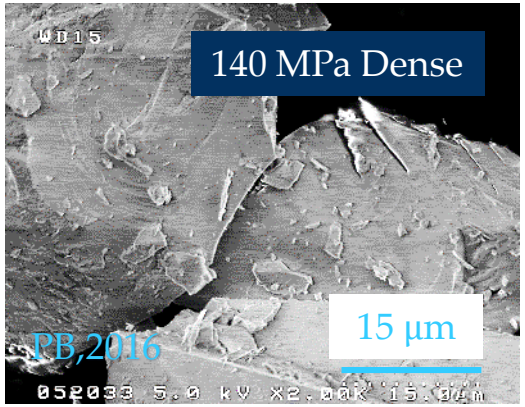


Crushed Ottawa F-65 30 MPa loose specimen 30 µm x1000

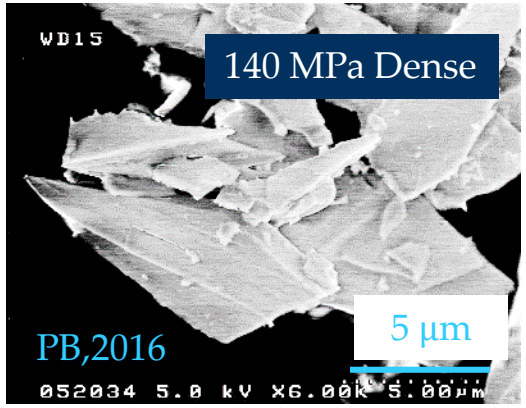
(5) Particles and asperities split in the middle



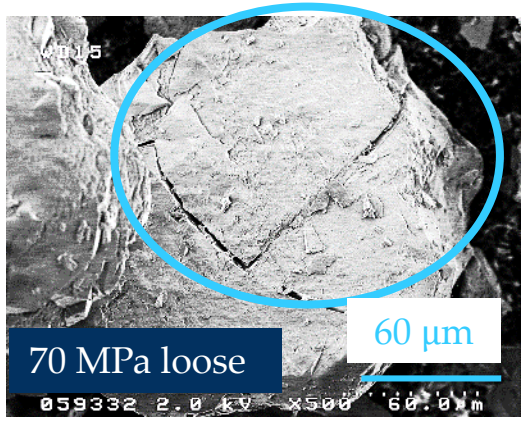
Original Ottawa sand F-65 200 µm x150



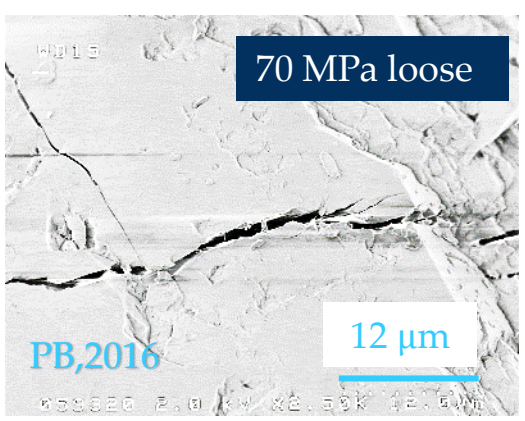
Crushed Ottawa F-65 140 MPa dense specimen 15 µm x2000



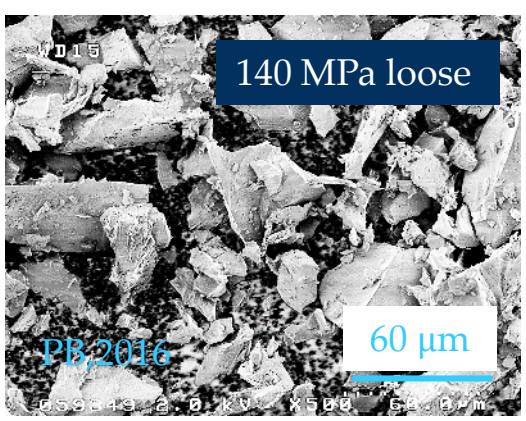
Crushed Ottawa F-65 140 MPa dense specimen 5 µm x6000



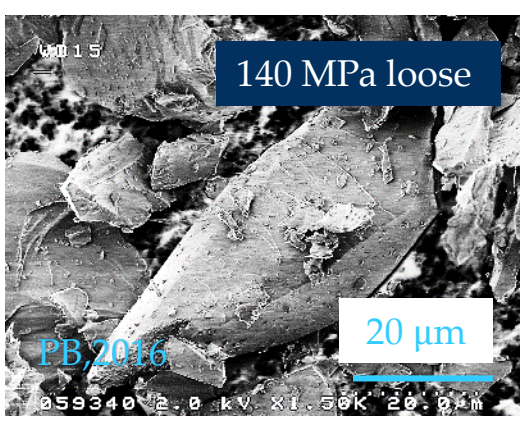
Crushed Ottawa F-65 70 MPa loose specimen 60 µm x500



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



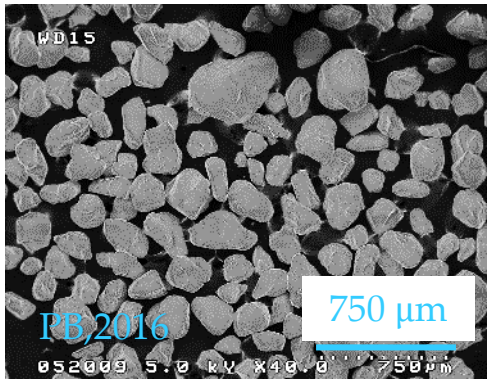
Crushed Ottawa F-65 140 MPa loose specimen 60 µm x500



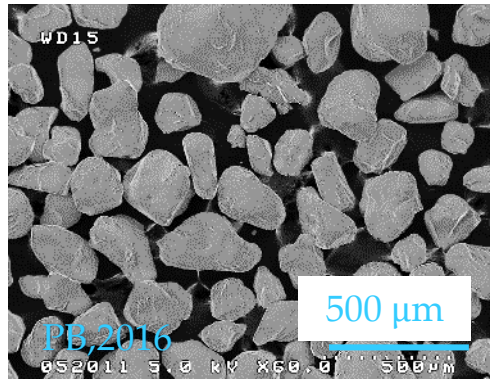
Crushed Ottawa F-65 140 MPa loose specimen 20 µm x1500

Images on original sand

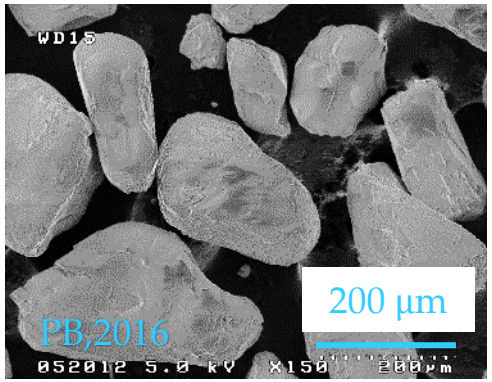
Ottawa sand F-65 grains pre-compression



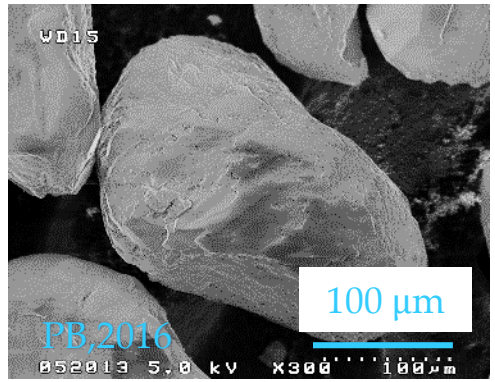
Original Ottawa sand F-65 750 µm
x40



Original Ottawa sand F-65 500 µm
x60



Original Ottawa sand F-65 200 µm
x150

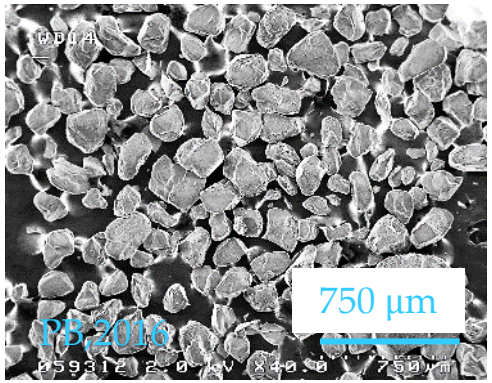


Original Ottawa sand F-65 100 µm
x300

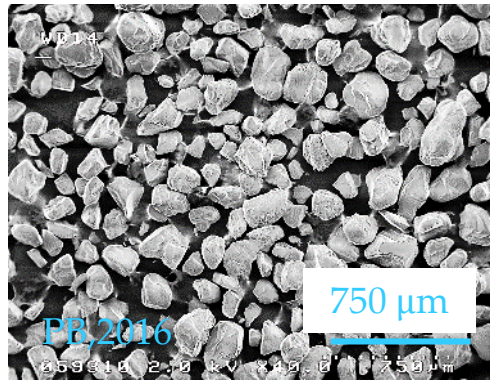
Images on loose prepared specimens

Loose prepared specimens
1D-Compression σ'_{vmax}=30 MPa

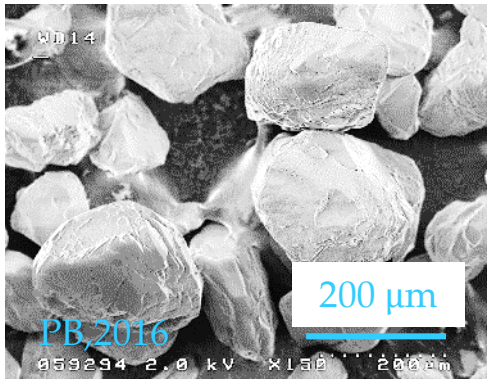
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens



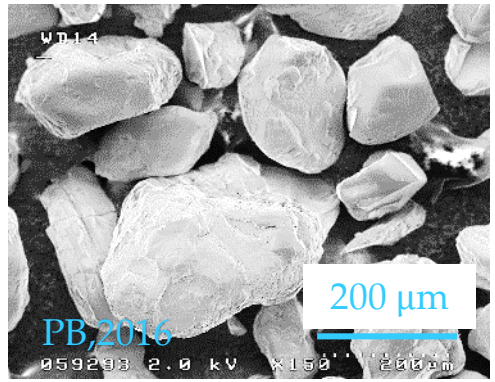
Crushed Ottawa F-65 30 MPa loose specimen 750 µm x40



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

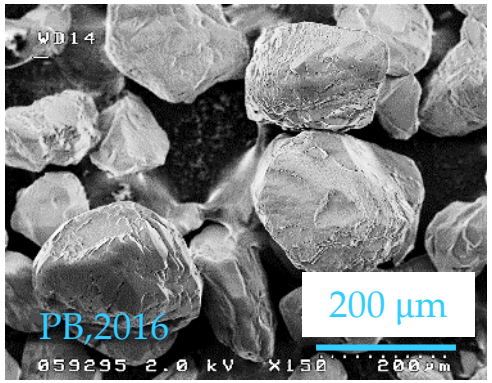


Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150

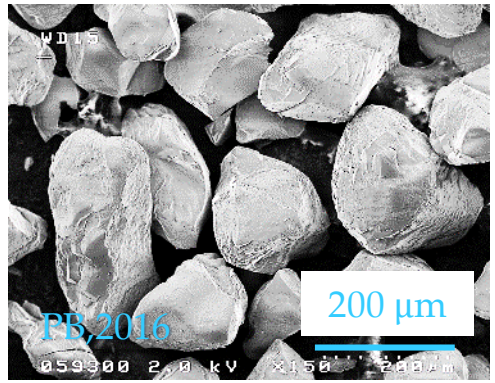


Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150

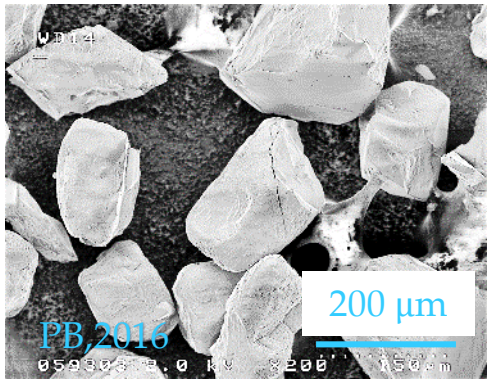
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens



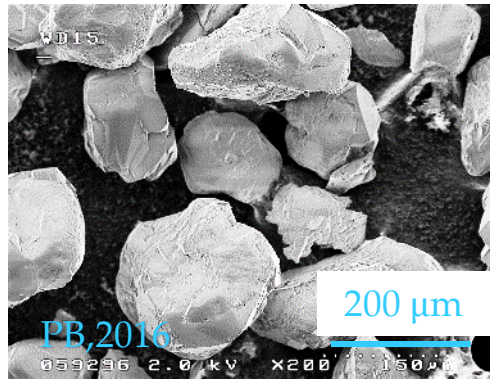
Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150



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



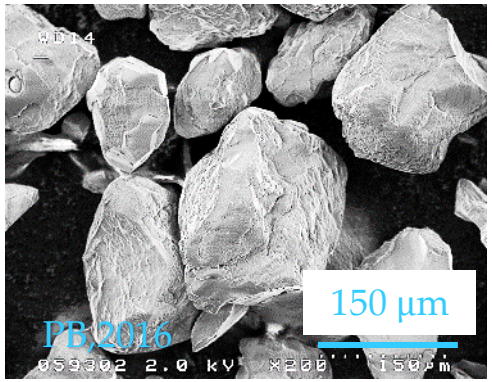
Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150



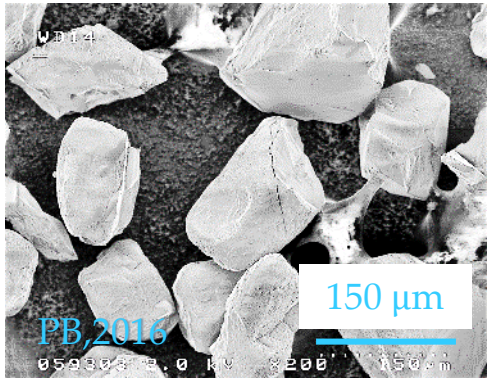
Crushed Ottawa F-65 30 MPa loose specimen 200 µm x150

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

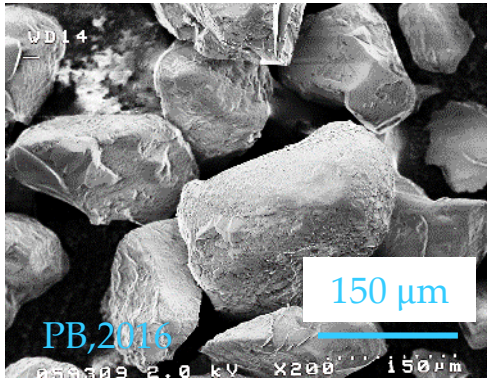
Crushed Ottawa F-65 30 MPa loose specimen 150 µm x200



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

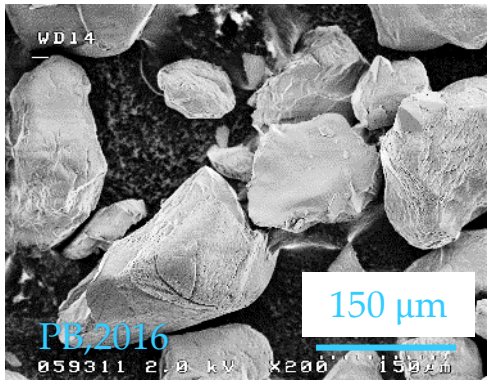


Crushed Ottawa F-65 30 MPa loose specimen 150 µm x200

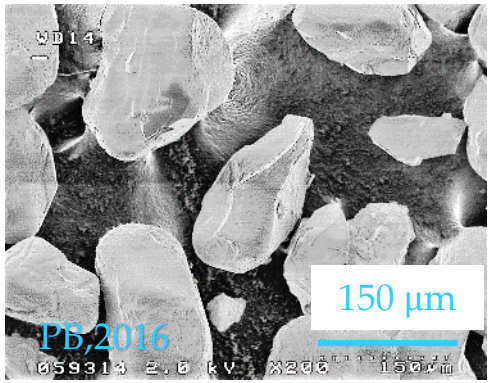


Crushed Ottawa F-65 30 MPa loose specimen 150 µm x200

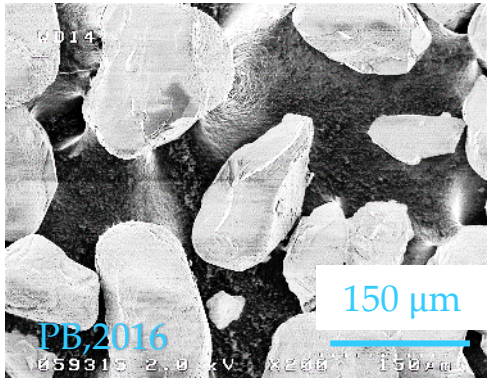
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens



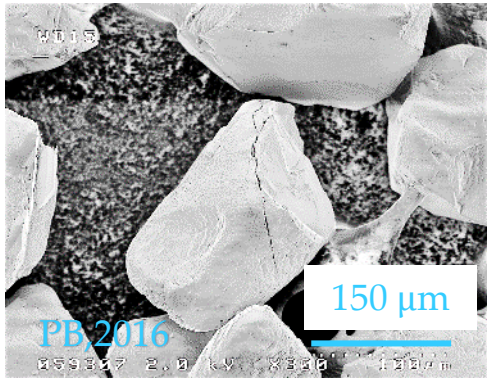
Crushed Ottawa F-65 30 MPa loose specimen150µm x200



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

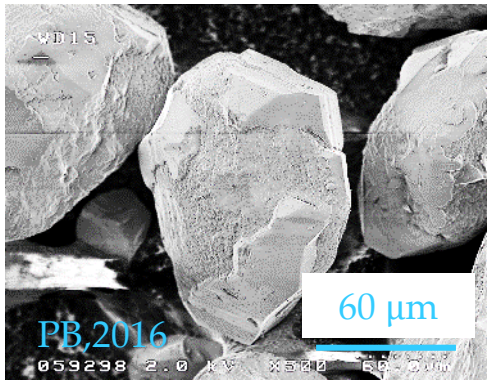


Crushed Ottawa F-65 30 MPa loose specimen 150 µm x200

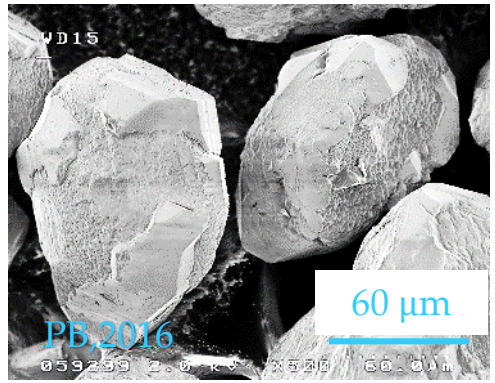


Crushed Ottawa F-65 30 MPa loose specimen 100 µm x300

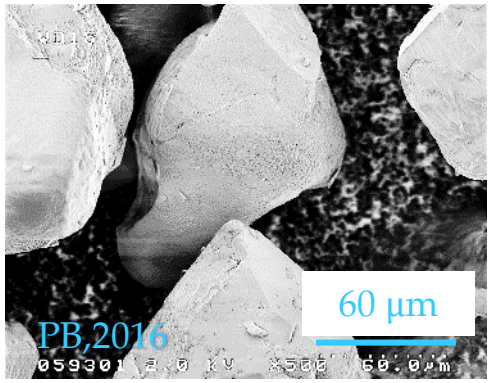
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens



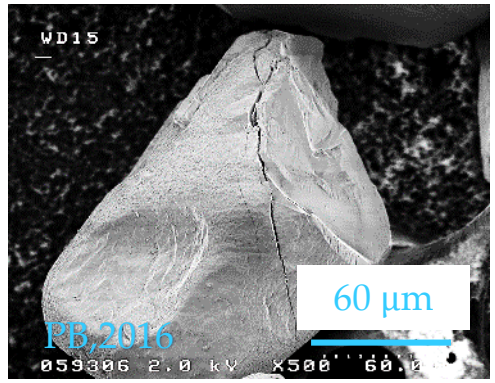
Crushed Ottawa F-65 30 MPa loose specimen 60 µm x500



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

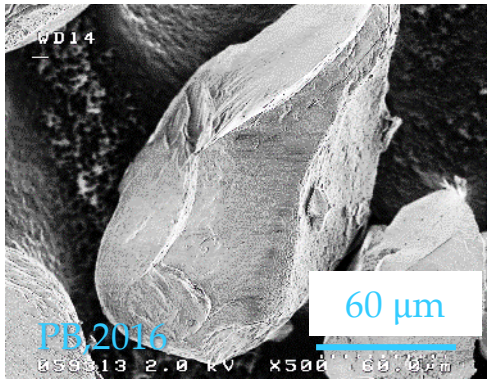


Crushed Ottawa F-65 30 MPa loose specimen 60 µm x500

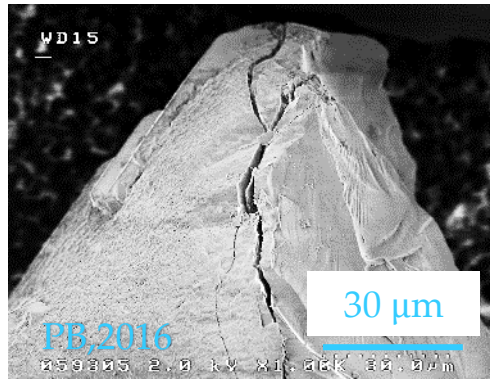


Crushed Ottawa F-65 30 MPa loose specimen 60 µm x500

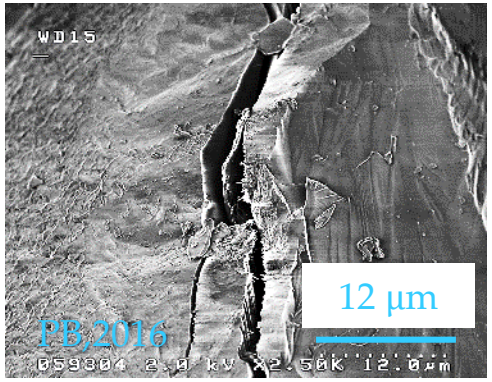
Ottawa sand F-65 grains post 1D-compression 30 MPa loose specimens



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



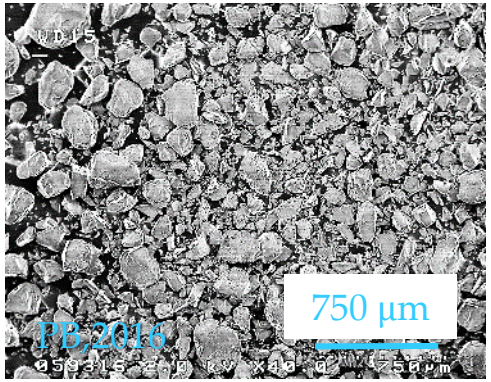
Crushed Ottawa F-65 30 MPa loose specimen 30 µm x1000



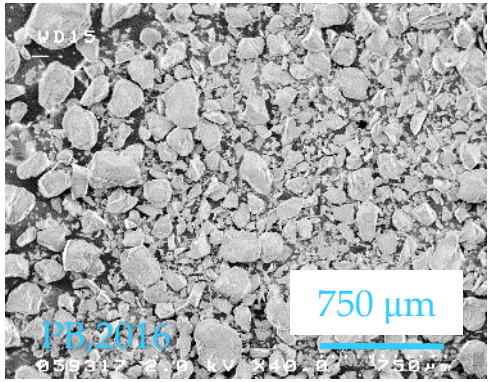
Crushed Ottawa F-65 30 MPa loose specimen 12 µm x2500

Loose prepared specimens 1D-Compression σ'_{vmax}=70 MPa

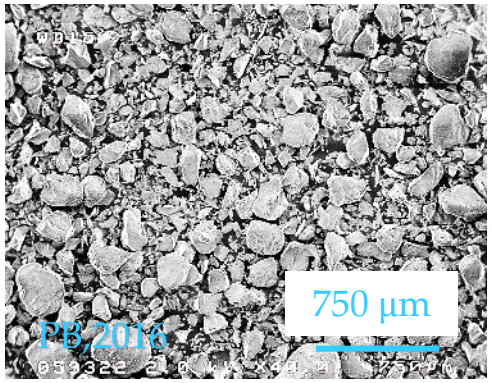
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens



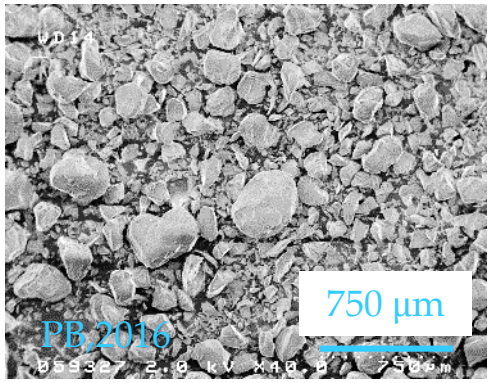
Crushed Ottawa F-65 70 MPa loose specimen 750 µm x40



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

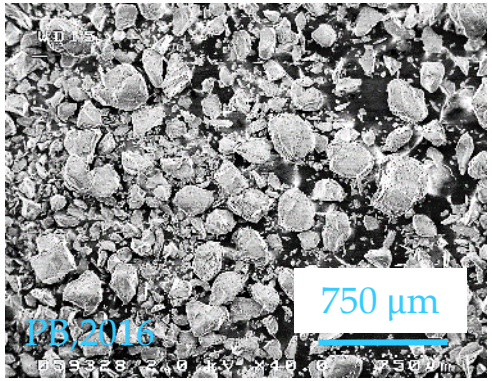


Crushed Ottawa F-65 70 MPa loose specimen 750 µm x40

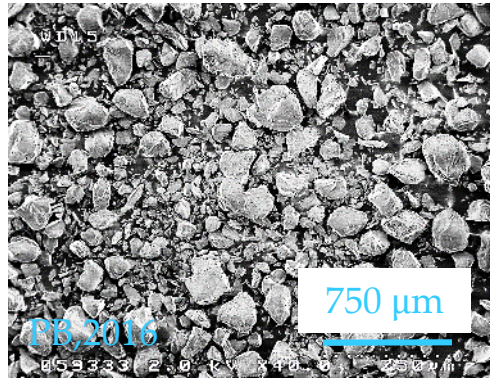


Crushed Ottawa F-65 70 MPa loose specimen 750 µm x40

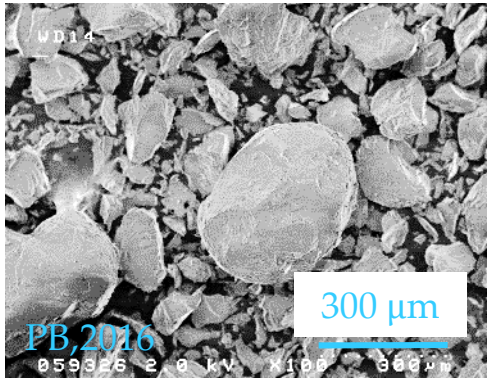
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens



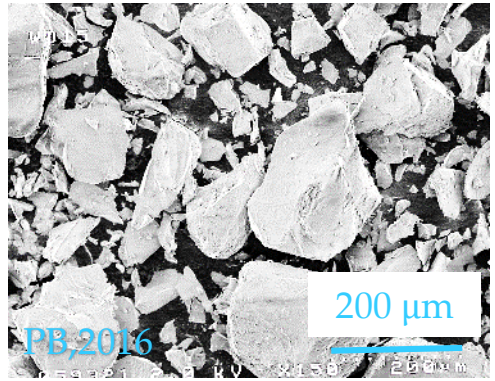
Crushed Ottawa F-65 70 MPa loose specimen 750 µm x40



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

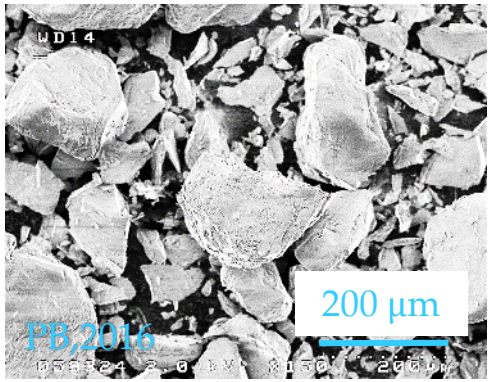


Crushed Ottawa F-65 70 MPa loose specimen 300 µm x100

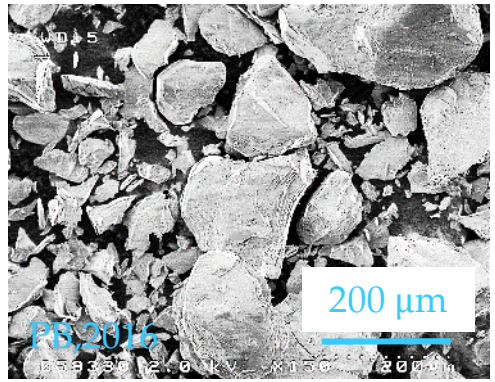


Crushed Ottawa F-65 70 MPa loose specimen 200 µm x150

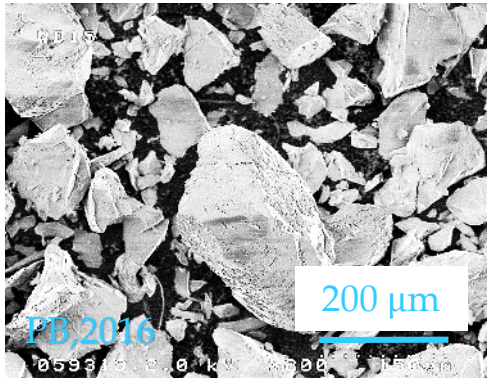
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens



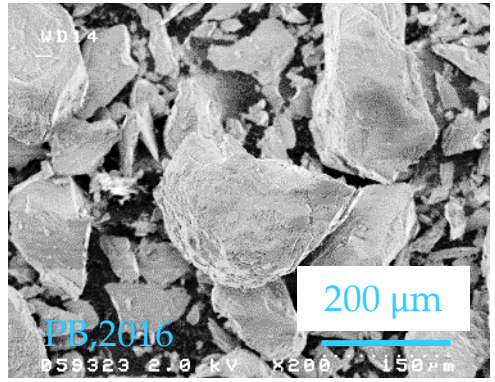
Crushed Ottawa F-65 70 MPa loose specimen 200 µm x150



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

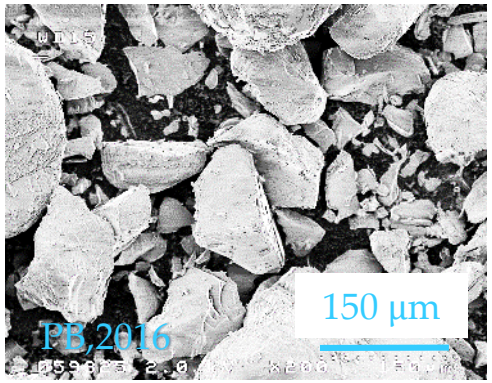


Crushed Ottawa F-65 70 MPa loose specimen 200 µm x150

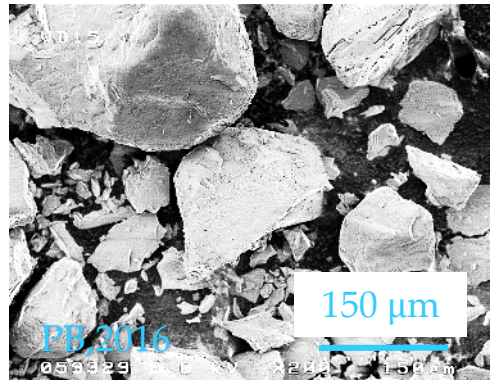


Crushed Ottawa F-65 70 MPa loose specimen 200 µm x150

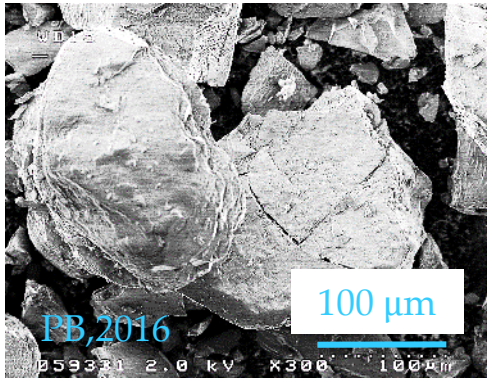
Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens



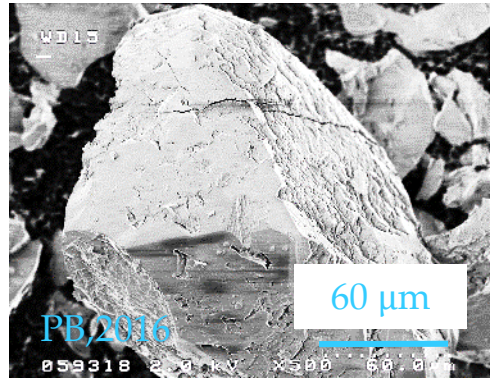
Crushed Ottawa F-65 70 MPa loose specimen 150 µm x200



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

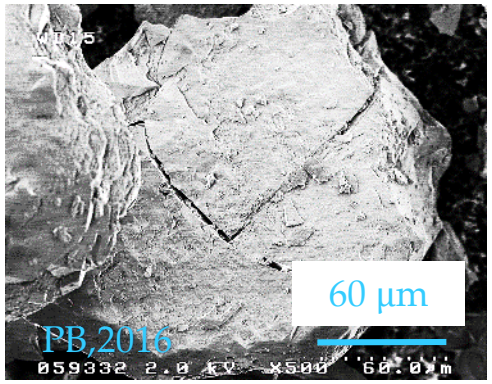


Crushed Ottawa F-65 70 MPa loose specimen 100 µm x300

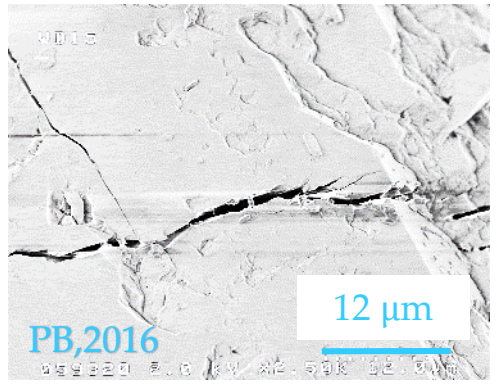


Crushed Ottawa F-65 70 MPa loose specimen 60 µm x500

Ottawa sand F-65 grains post 1D-compression 70 MPa loose specimens



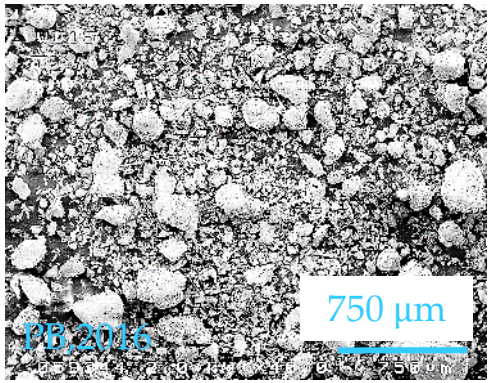
Crushed Ottawa F-65 70 MPa loose specimen 60 µm x500



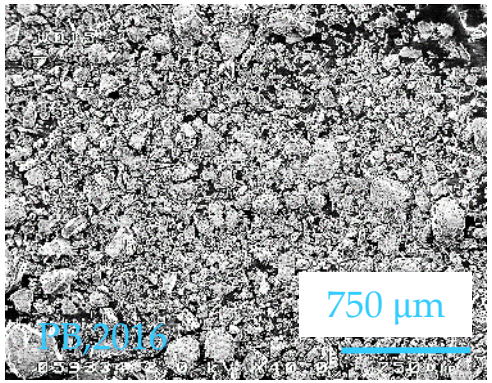
Crushed Ottawa F-65 70 MPa loose specimen 12 µm x2500

Loose prepared specimens
1D-Compression σ'_{vmax}=140 MPa

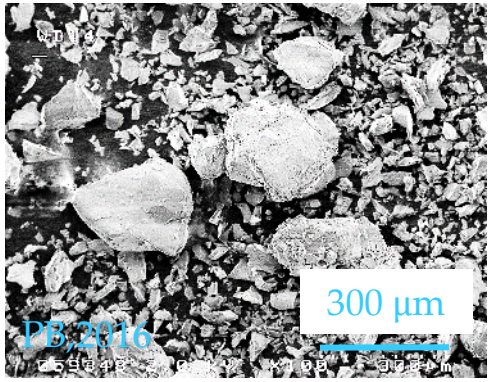
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens



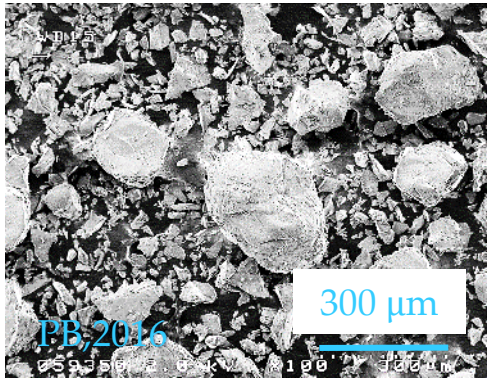
Crushed Ottawa F-65 140 MPa loose specimen 750 µm x40



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

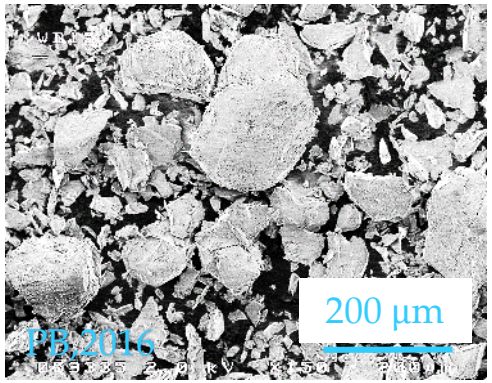


Crushed Ottawa F-65 140 MPa loose specimen 300 µm x100

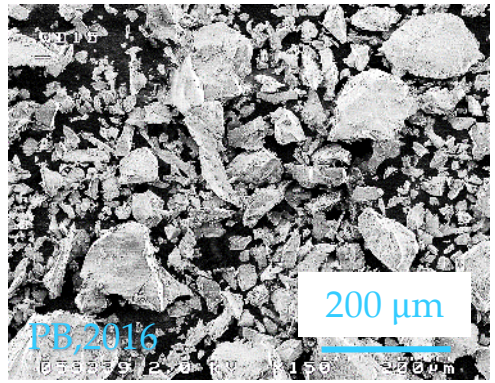


Crushed Ottawa F-65 140 MPa loose specimen 300 µm x100

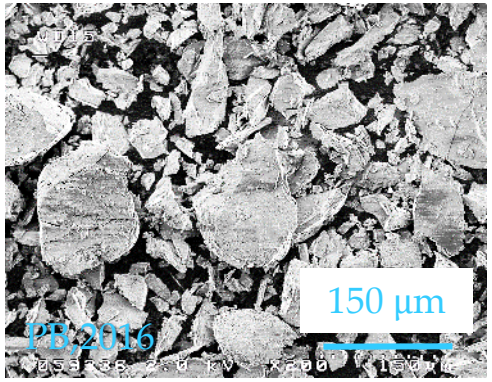
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens



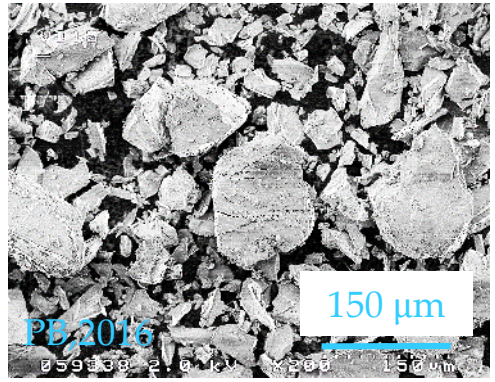
Crushed Ottawa F-65 140 MPa loose specimen 200 µm x150



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

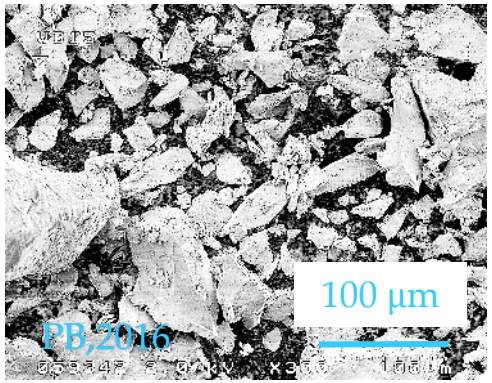


Crushed Ottawa F-65 140 MPa loose specimen 150 µm x200

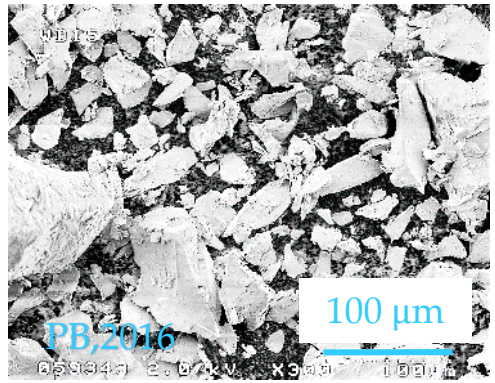


Crushed Ottawa F-65 140 MPa loose specimen 150 µm x200

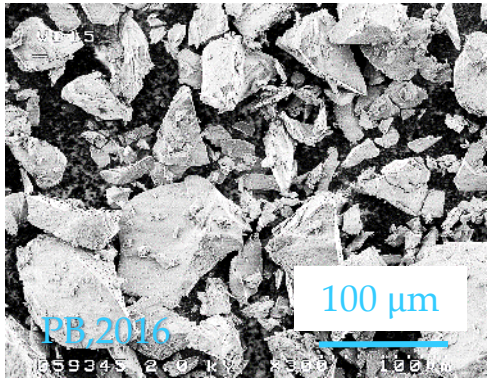
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens



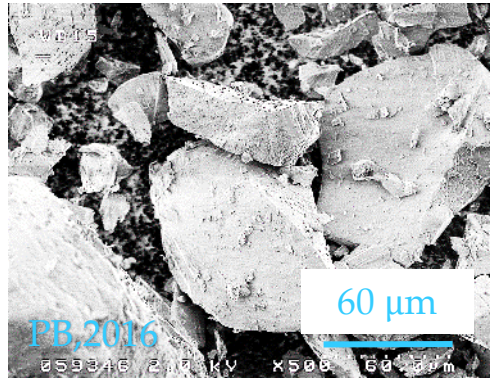
Crushed Ottawa F-65 140 MPa loose specimen 100 µm x300



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

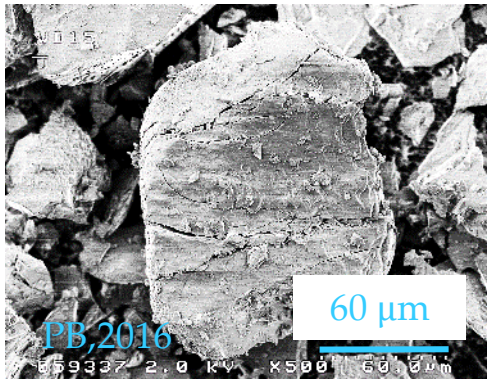


Crushed Ottawa F-65 140 MPa loose specimen 100 µm x300

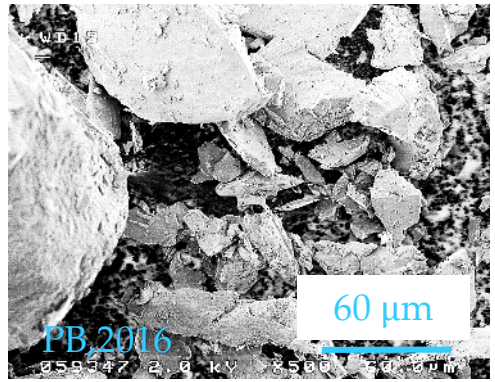


Crushed Ottawa F-65 140 MPa loose specimen 60 µm x500

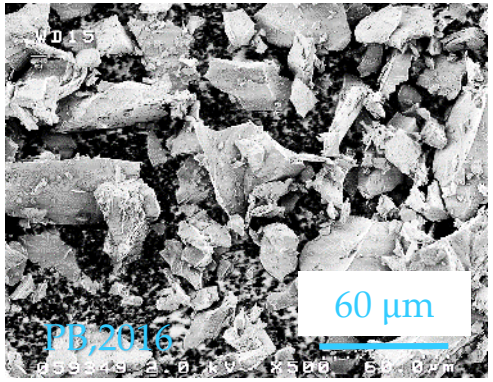
Ottawa sand F-65 grains post 1D-compression 140 MPa loose specimens



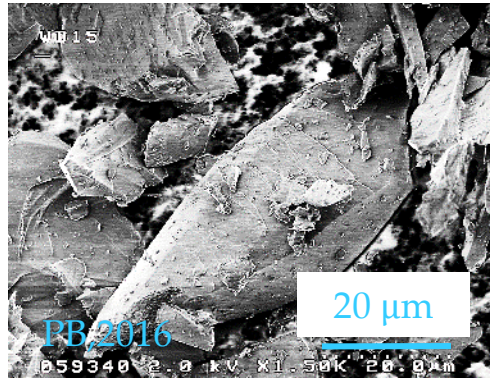
Crushed Ottawa F-65 140 MPa loose specimen 60 µm x500



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



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

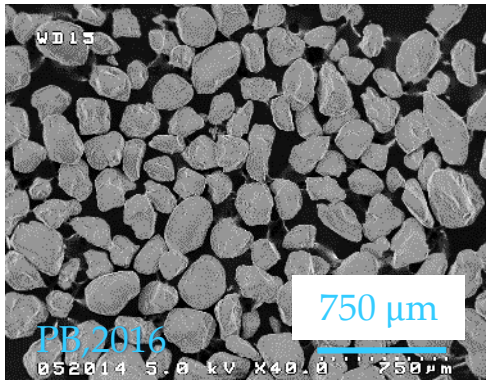


Crushed Ottawa F-65 140 MPa loose specimen 20 µm x1500

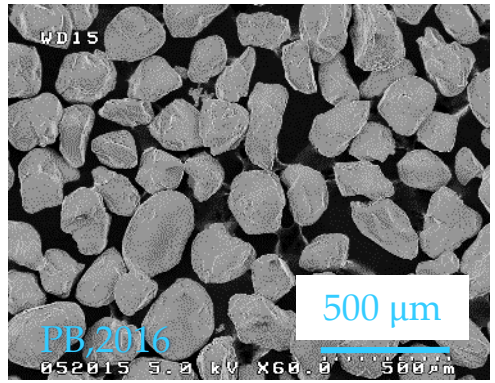
Images on dense prepared specimens

Dense prepared specimens 1D-Compression σ'_{vmax}=30 MPa

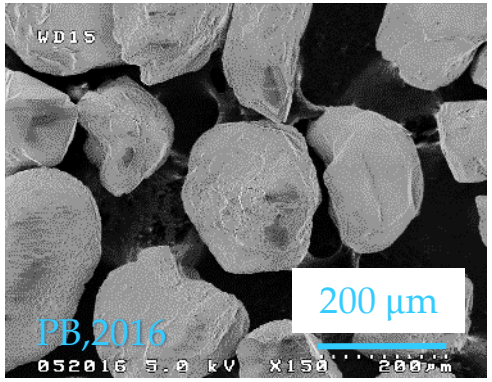
Ottawa sand F-65 grains post 1D-compression 30 MPa dense specimens



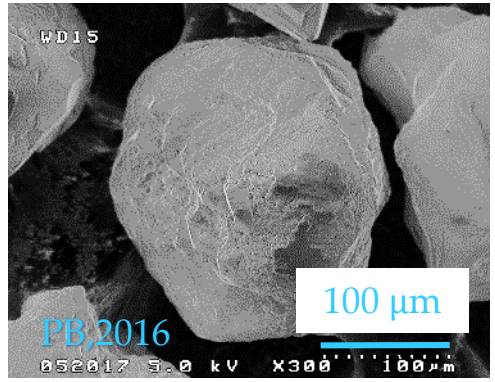
Crushed Ottawa F-65 30 MPa dense Specimen 750 µm x40



Crushed Ottawa F-65 30 MPa dense Specimen 500 µm x60



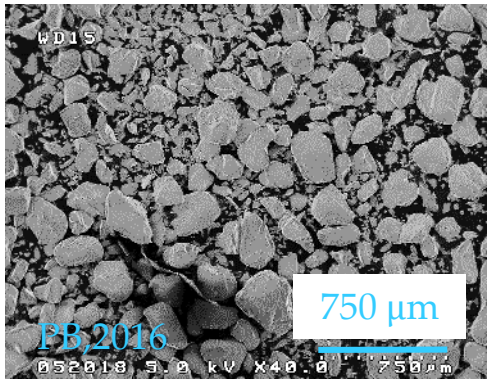
Crushed Ottawa F-65 30 MPa dense Specimen 200 µm x150



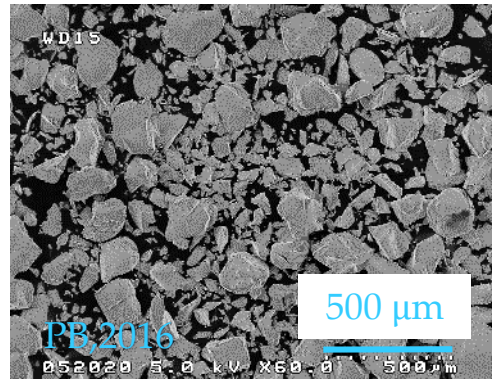
Crushed Ottawa F-65 30 MPa dense Specimen 100 µm x300

Dense prepared specimens 1D-Compression σ'_{vmax}=70 MPa

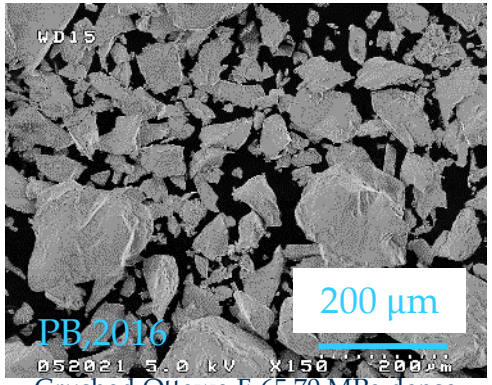
Ottawa sand F-65 grains post 1D-compression 70 MPa dense specimens



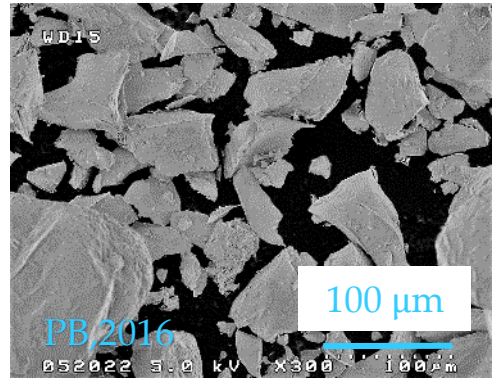
Crushed Ottawa F-65 70 MPa dense specimen 750 µm x40



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

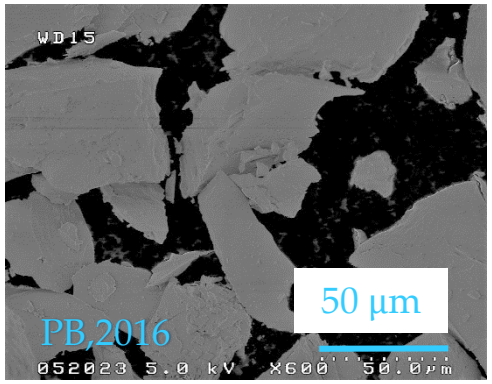


Crushed Ottawa F-65 70 MPa dense specimen 200 µm x150



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

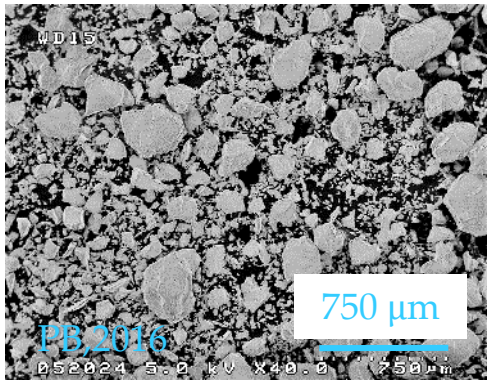
Ottawa sand F-65 grains post 1D-compression 70 MPa dense specimens



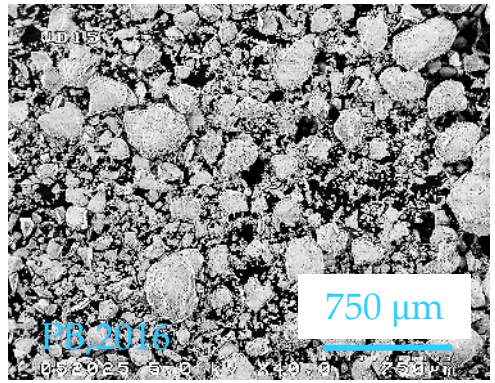
Crushed Ottawa F-65 70 MPa dense specimen 50 µm x600

Dense prepared specimens 1D-Compression σ'_{vmax}=140 MPa

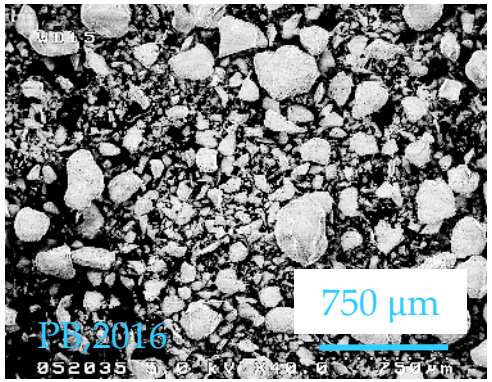
Ottawa sand F-65 grains post 1D-compression 140 MPa dense specimens



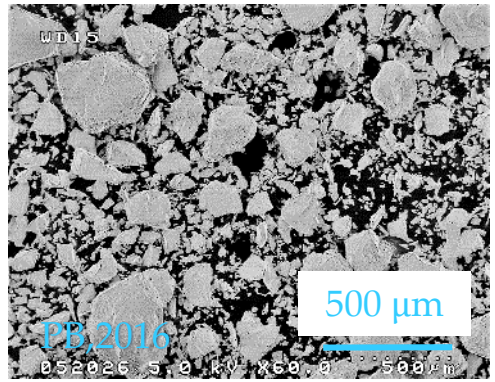
Crushed Ottawa F-65 140 MPa dense specimen 750 µm x40



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

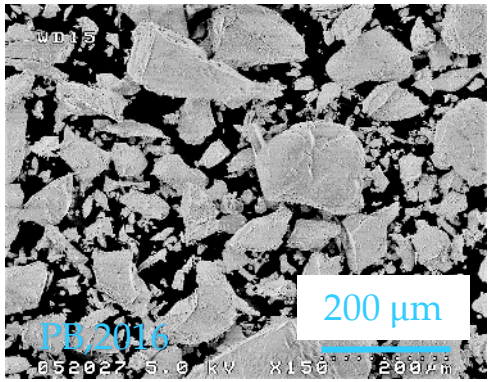


Crushed Ottawa F-65 140 MPa dense specimen 20 750 µm x40

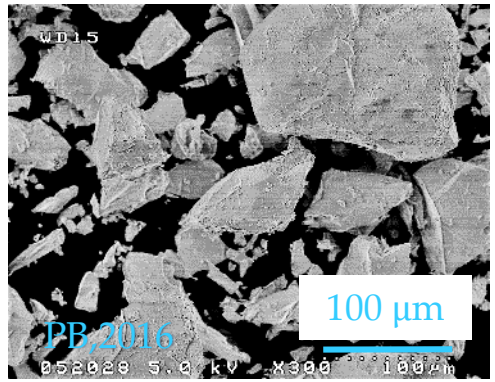


Crushed Ottawa F-65 140 MPa dense specimen 21 500 µm x60

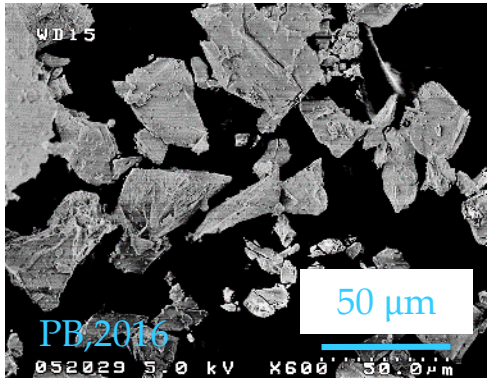
Ottawa sand F-65 grains post 1D-compression 140 MPa dense specimens



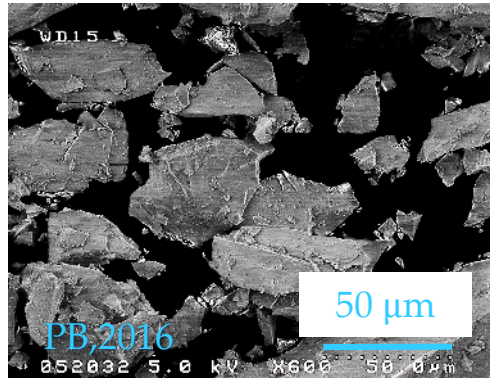
Crushed Ottawa F-65 140 MPa dense specimen 200 µm x150



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

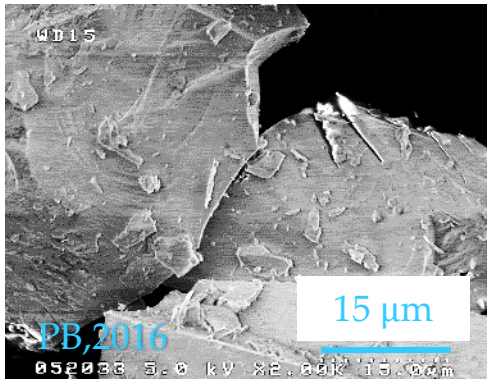


Crushed Ottawa F-65 140 MPa dense specimen 50 µm x600

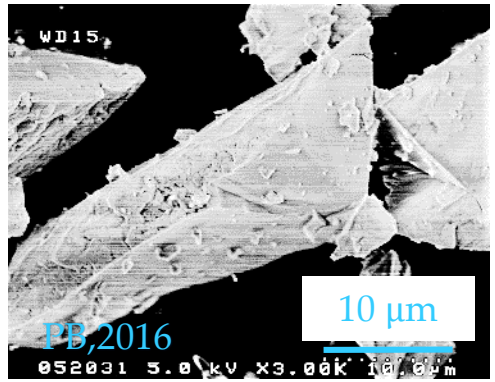


Crushed Ottawa F-65 140 MPa dense specimen 50 µm x600

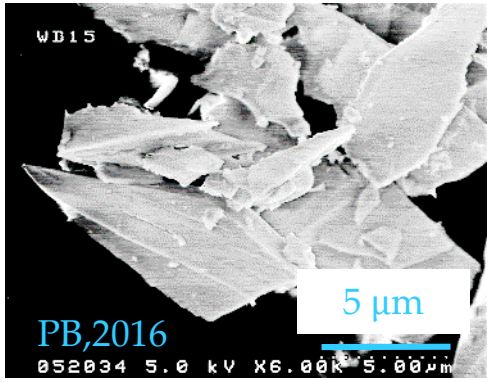
Ottawa sand F-65 grains post 1D-compression 140 MPa dense specimens



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

Questions?

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