Earthquake-triggered soil liquefaction caused extensive damage and heavy economic losses in Christchurch during the 2010-2011 Canterbury earthquakes. The most severe manifestations of liquefaction were associated with the presence of natural deposits of clean sands and silty sands of fluvial origin. However:

- Liquefaction resistance of fines-containing sands is commonly inferred from empirical relationships based on clean sands with less than 5% fines. Hence, existing evaluation methods have poor accuracy when applied to silty sands.
- Existing methods do not quantitatively appropriately the influence on liquefaction resistance of soil fabric and structure, which are unique to a specific depositional environment.

### 2 Scope of Research

To investigate and quantify the influence of fines content, soil fabric (i.e. arrangement of soil particles) and structure (e.g. layering, segregation) on the undrained cyclic behaviour and liquefaction resistance of fines-containing sands soils from Christchurch using:

- A series of Direct Simple Shear (DSS) tests on soil specimens reconstituted in the laboratory with the water sedimentation technique.
- Comparison of DSS results against Triaxial tests already performed at the University of Canterbury on undisturbed (Gel-Push, Dames & Moore) and reconstituted (moist tamping) specimens of similar soils.

The poster summarizes observations on the effects of fines content and specimen density from selected DSS tests.

### 3 Direct Simple Shear (DSS) Test

Free-field response of level ground deposits under earthquake excitation is usually associated with simple shear mode of deformation of a soil element (Figure 1). The Direct Simple Shear (DSS) test was introduced in order to better approximate these loading conditions with respect to the triaxial test commonly used in geotechnical applications.

- Specimen with circular cross-section wrapped within plain latex membrane (similarly to conventional triaxial testing devices).
- Lateral (cell) pressure applied through a confining chamber by means of compressed air.
- Back Pressure can be used for specimen saturation.

### 4 Water Sedimentation

To obtain soil specimens with fabric and structure resembling those typical of fluvial soil deposits, which are common in Christchurch, specimens are prepared in the laboratory using the water sedimentation technique (Figure 3):

1. Soil is poured in a mould filled with water using a funnel.
2. After sedimentation, water in excess is drained through the specimen and removed from the mould. The top surface of the specimen is levelled before the top cap is positioned on the specimen.
3. Higher densities (Dc = 61 mm for sand, >75% for RZ3 sand) can be achieved by using additional weights or applying gentle vibrations on the table using a mallet.
4. The procedure yields specimens of approximately 61 mm in diameter and 15 mm in height.

Water loading can be performed either in a single stage or in multiple stages, so as to enforce either a segregated or a layered structure (Figure 4).

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### Test Results

Tests are performed on two sands, a silt, and sand-silt mixtures of soils from Christchurch (Figure 5) with the following characteristics (Figures 6 and 7):

- **R3 sand**: Uniform sand with sub-angular grains and relatively clean surfaces, sampled at 5.7 m depth in the suburb of Avonside.
- **R3 soils**: Sand-silt mixtures obtained by recombining different fractions (175 μm and >75 μm) of a fluvial silty sand with angular grains, sampled at 7.1 m depth in the suburb of Flexley.
- **R3-FCS0 sand-silt**: A gap-graded mixture with FC = 30% obtained by combining R3 sand with RZ6-FC100 silt.

The liquefaction resistance of R3 sand is significantly affected by the addition of fines (Figure 8). Specimens of R3-FCS0 sand-silt mixture exhibit lower liquefaction resistance than R3 sand with similar relative density.

For mixtures prepared with RZ6-FC9, the relationship between relative density and fines content (up to tested value of FC = 53%) appears independent from fines content.

RZ6-FC100 silt has lower liquefaction resistance than other tested soils despite its higher Dc.

### Conclusion

- All tested specimens attained a condition of initial liquefaction (r<sub>fc</sub> = 1.0), independently from host sand used in the preparation, fines content, or specimen density.
- R3 sand and R26-FC9, which are the host coarse-grained soils used in the preparation of sand-silt mixtures, show remarkably different liquefaction resistances at similar relative densities, with R3 sand having the greater liquefaction resistance. Changes in liquefaction resistance are consistent with changes in relative density during preparation: R3 sand exhibits a significant increase in liquefaction resistance, while this change is less significant in R26-FC9.
- The liquefaction resistance of R3 sand is significantly affected by the addition of fines (Figure 8). Specimens of R3-FCS0 sand-silt mixture exhibit lower liquefaction resistance than R3 sand with similar relative density.
- For mixtures prepared with RZ6-FC9, the relationship between relative density and fines content (up to tested value of FC = 53%) appears independent from fines content.

RZ6-FC100 silt has lower liquefaction resistance than other tested soils despite its higher Dc.