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"Liquefaction-Induced Ground Movements Effects"
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Post-Liquefaction Behaviour of Sands

A/Prof Rolando P Orense, Dr. Eng, PE, MASCE, MIPENZ
Department of Civil & Environmental Engineering
University of Auckland, New Zealand

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Introduction

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Post-liquefaction stress-strain response of sand is required for:

- estimating the magnitude of liquefaction-induced ground movements
  - lateral spreading of liquefied soil
  - liquefaction-induced settlements of structures
  - other liquefaction-related ground deformations
- can also be used to estimate the *p-y* curve for analysing soil-structure interaction (using Winkler method)

Previous studies (1)

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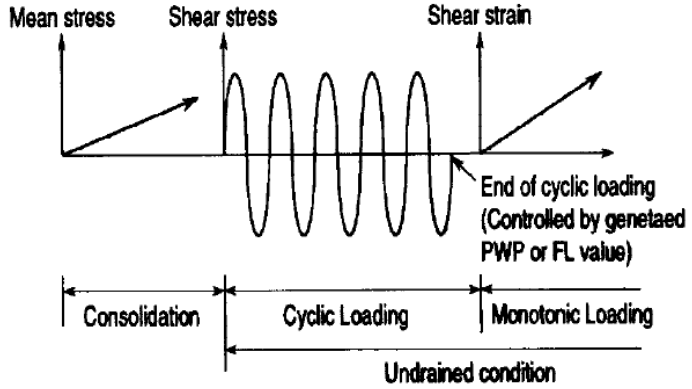
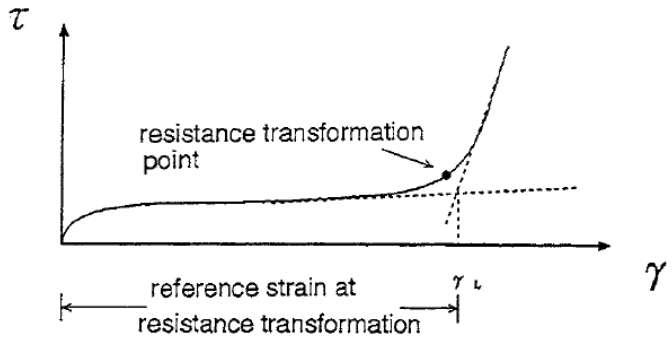
Work by Yasuda et al. (1995) on Toyoura sand

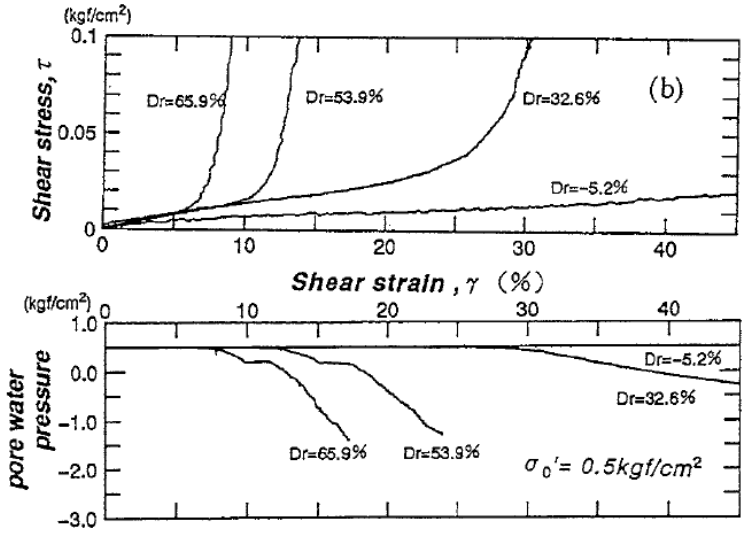
- Method:



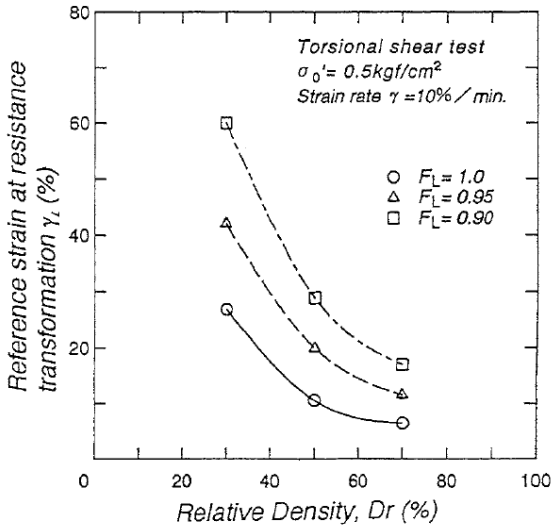
- Proposed model:



- Typical results (r_u=1.0, F_L=1.0, σ_0'=0.5 kgf/cm²)



- Effect of D_r & F_L



Previous studies (2)

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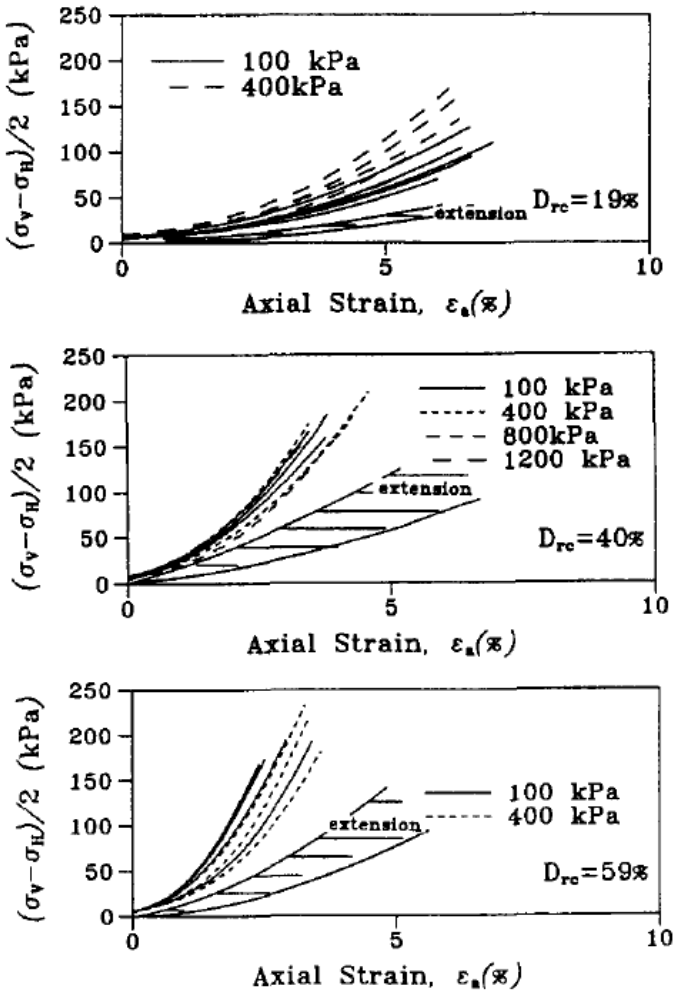
Work by Vaid & Thomas (1995) on Fraser River sand



- The sand that developed a 100% pore-pressure ratio deformed initially with an **essentially zero stiffness**, which then increased with the level of strain, until at some strain level it became constant.
- The **rate of build-up of deviator stress** with strain **increased with relative density**, and the **strain at which stiffness became essentially constant decreased** with an **increase in the relative density**.
- No indication of any residual strength condition on post-liquefaction loading was apparent, regardless of the density state or the mode of loading.

Materials used

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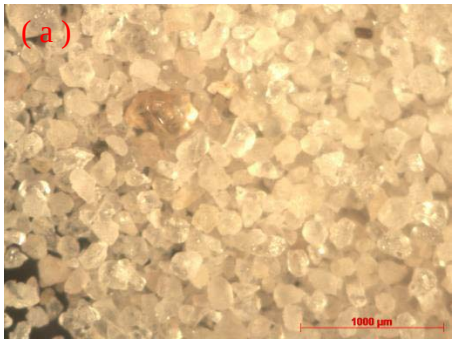
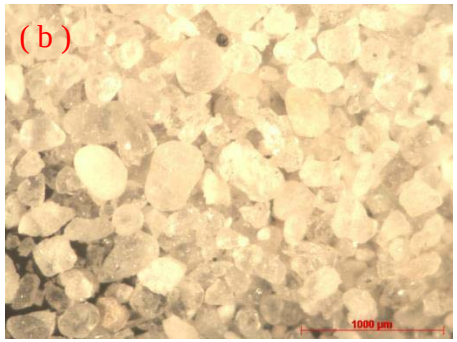
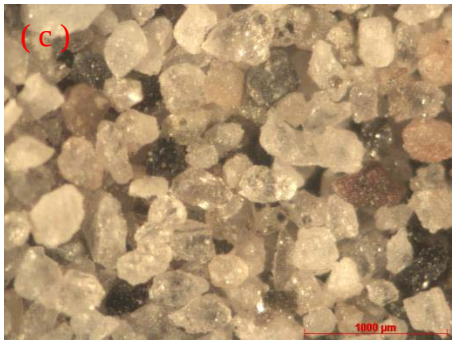


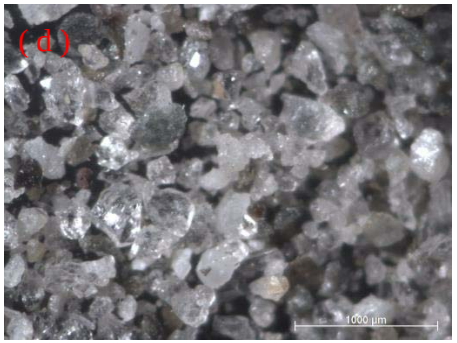
(a) Redhill-110 sand



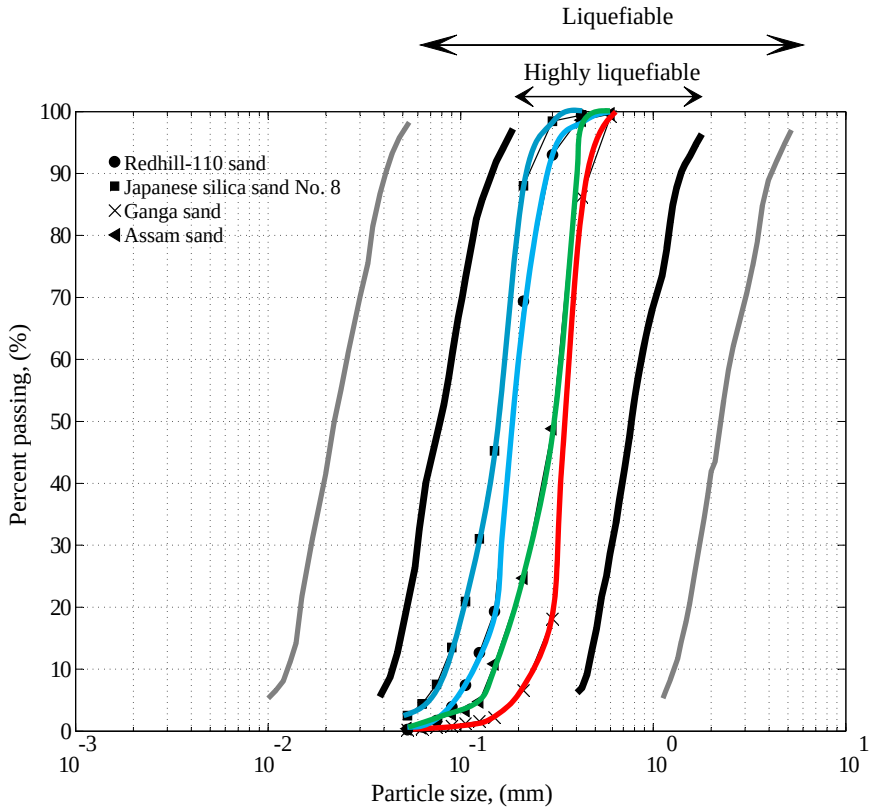
(b) Silica sand No. 8 (Japan)



(c) Assam sand (India)



(d) Ganga sand (India)



Sand name	Specific gravity, G_s	Mean Diam. D_{50} (mm)	Max. void ratio, e_{max}	Min. void ratio, e_{min}
Redhill-110 (UK)	2.65	0.18	1.035	0.608
Silica sand # 8 (Japan)	2.65	0.16	1.385	0.797
Assam sand (India)	2.68	0.30	0.962	0.622
Ganga sand (India)	2.67	0.35	1.003	0.853

Testing scheme

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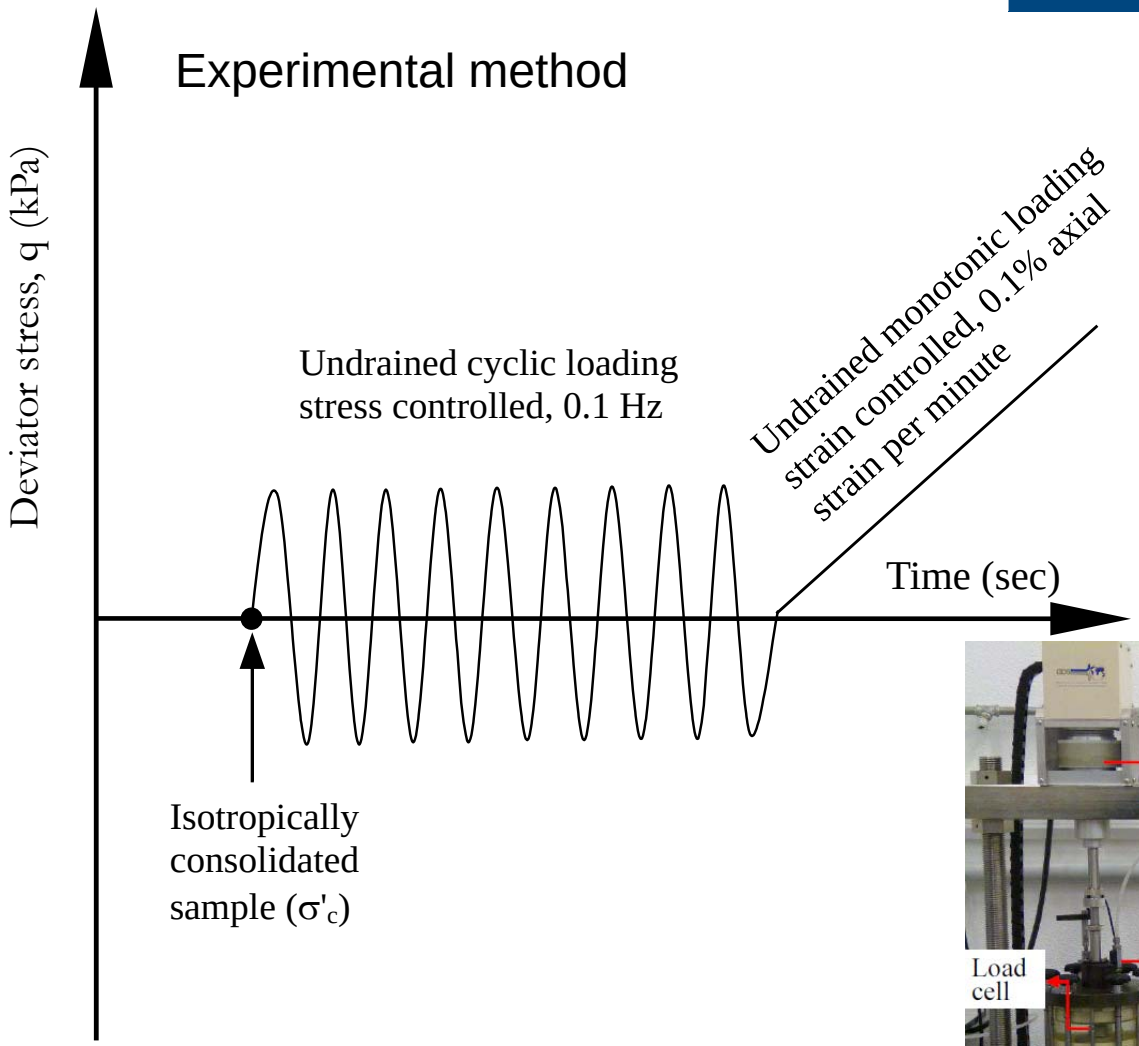
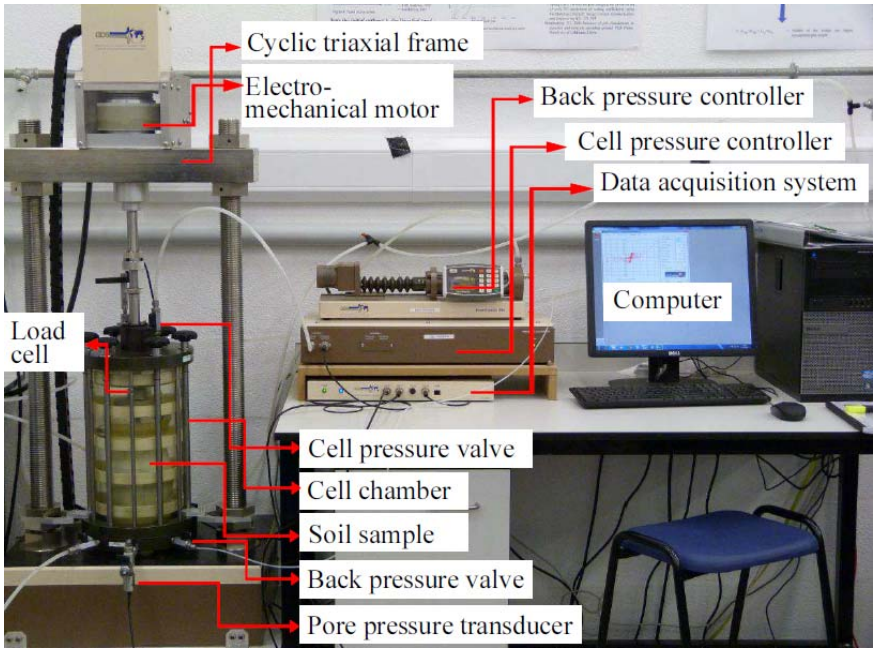
Experimental method





Cyclic Triaxial Apparatus
(SAGE Lab, Univ. of Surrey)

Representative results

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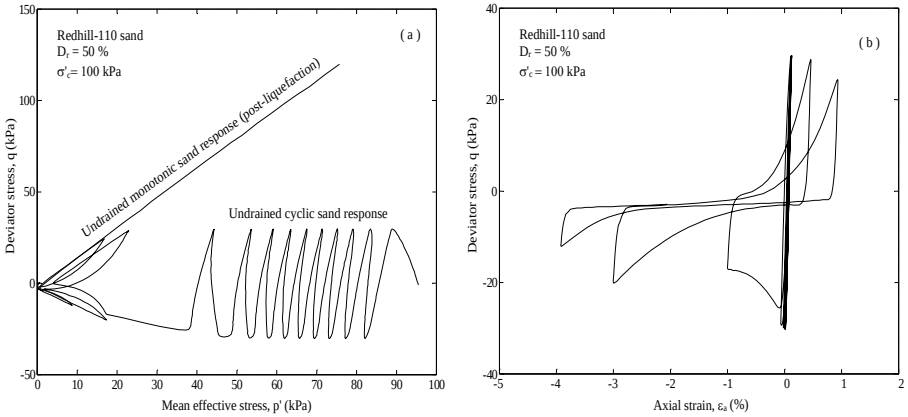
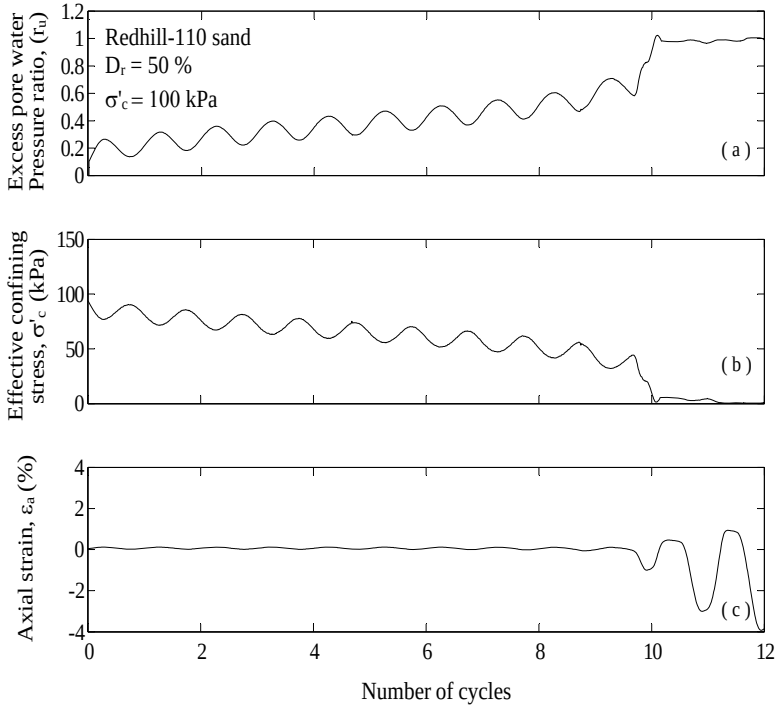
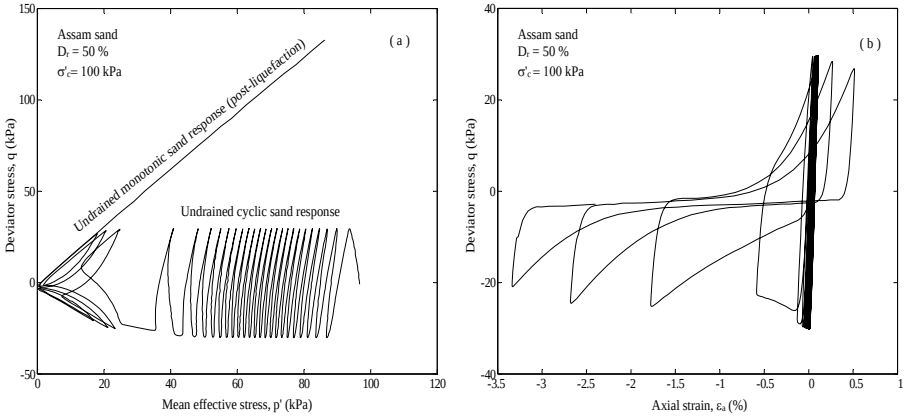
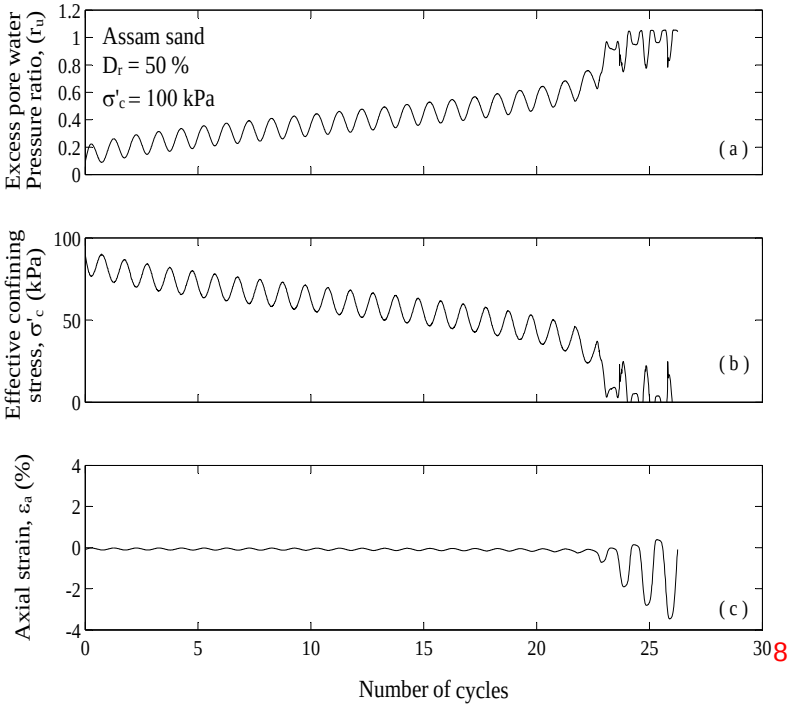
Redhill-110 Sand



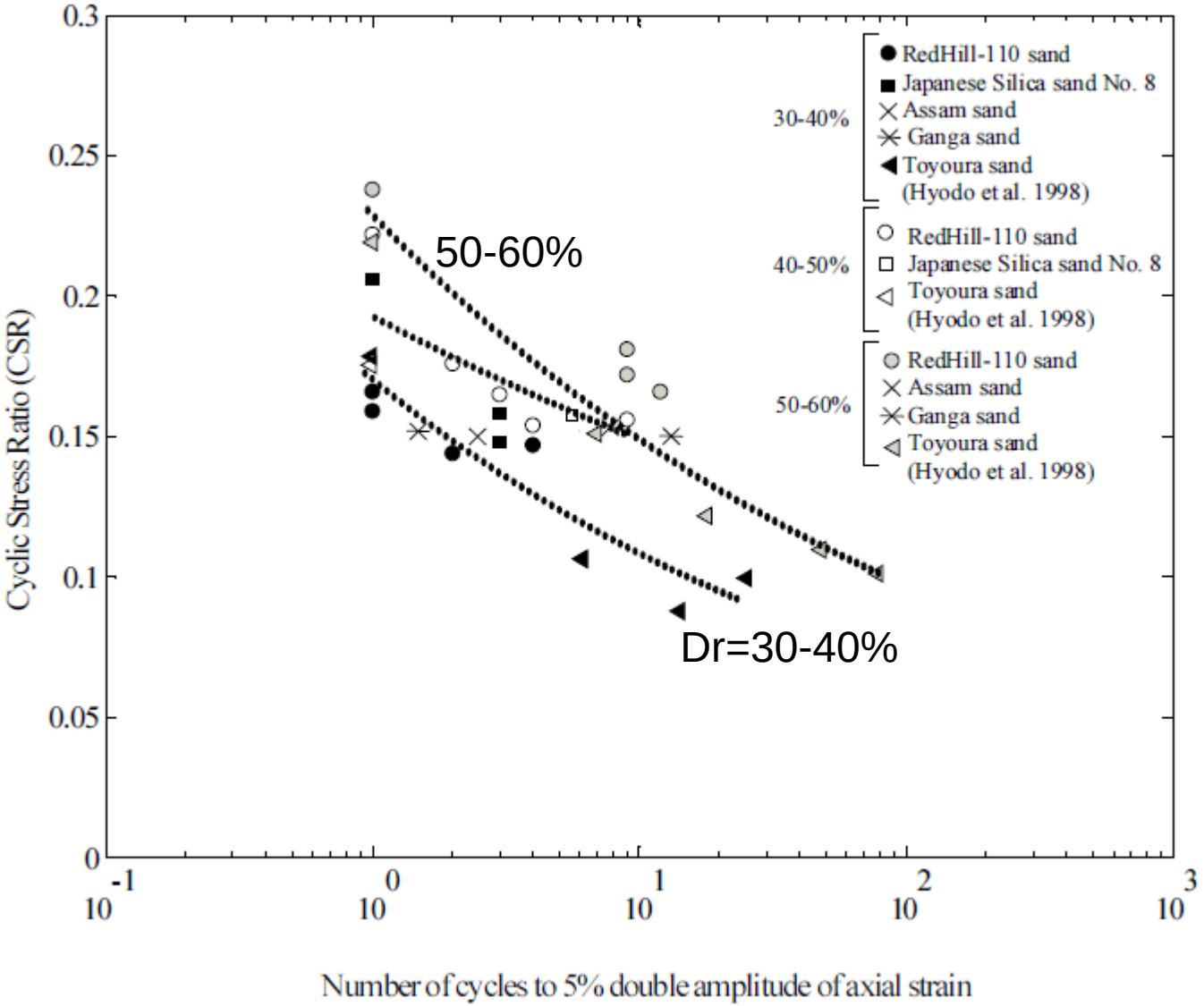


Assam Sand





Liquefaction curves



Post-liquefaction response (1)

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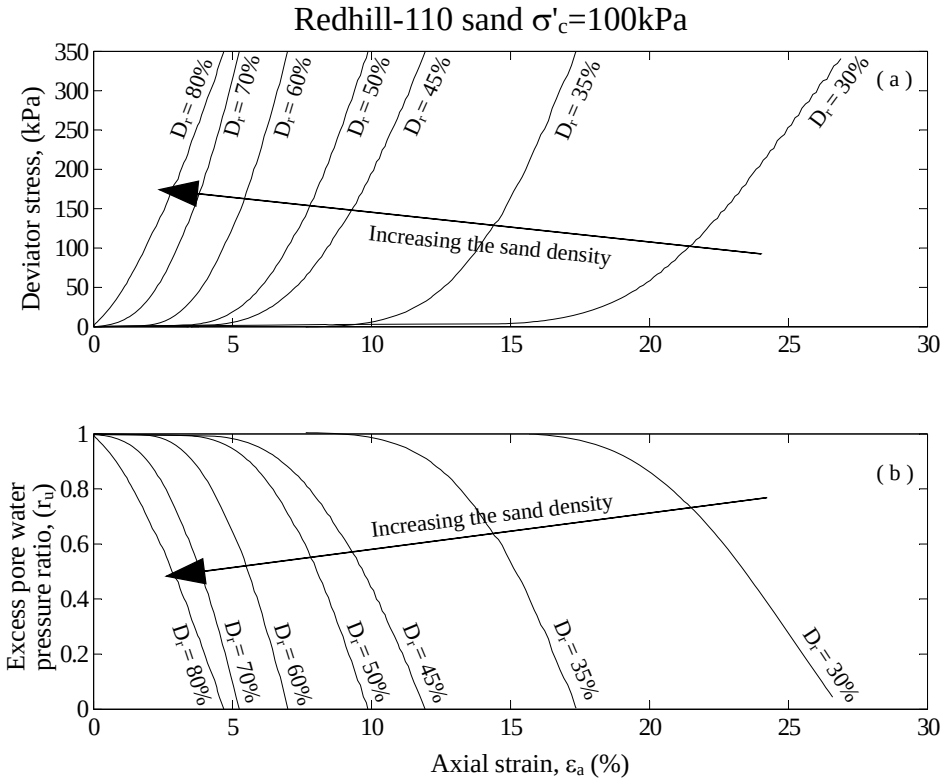
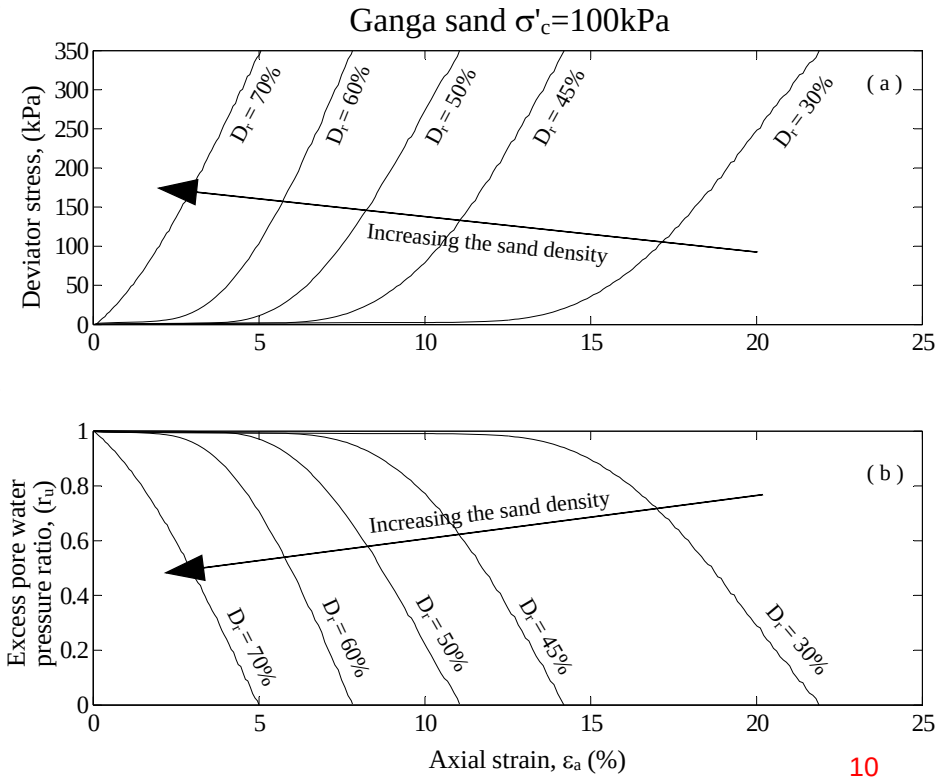
Redhill-110 Sand



Ganga Sand



Post-liquefaction response (2)

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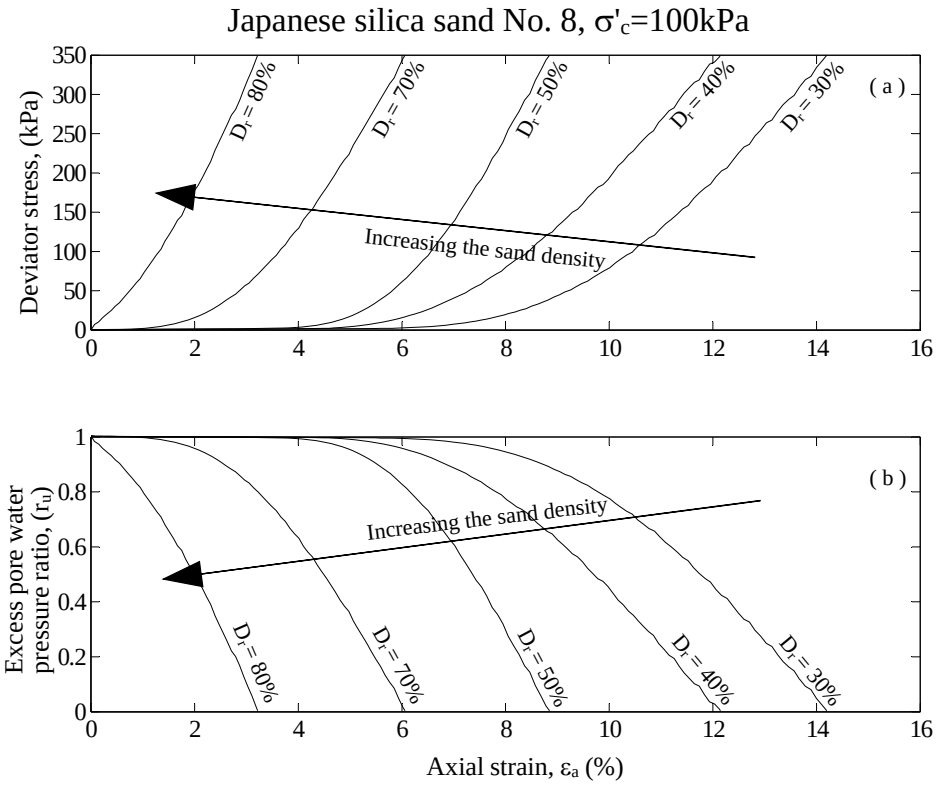
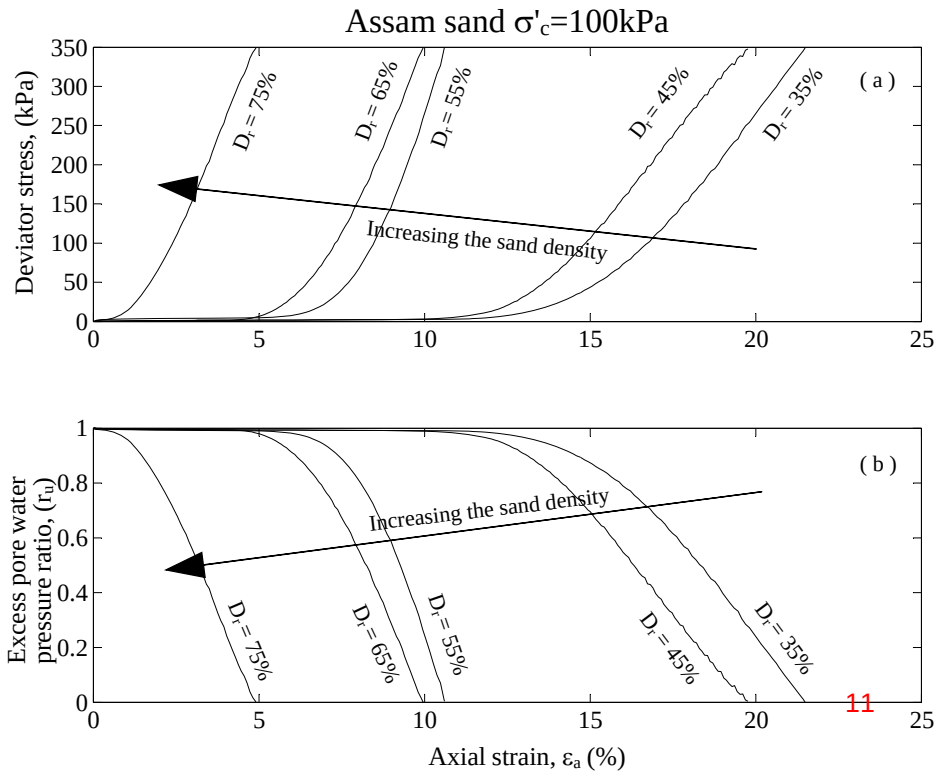
Japanese Silica Sand



Assam Sand



Post-liquefaction response (3)

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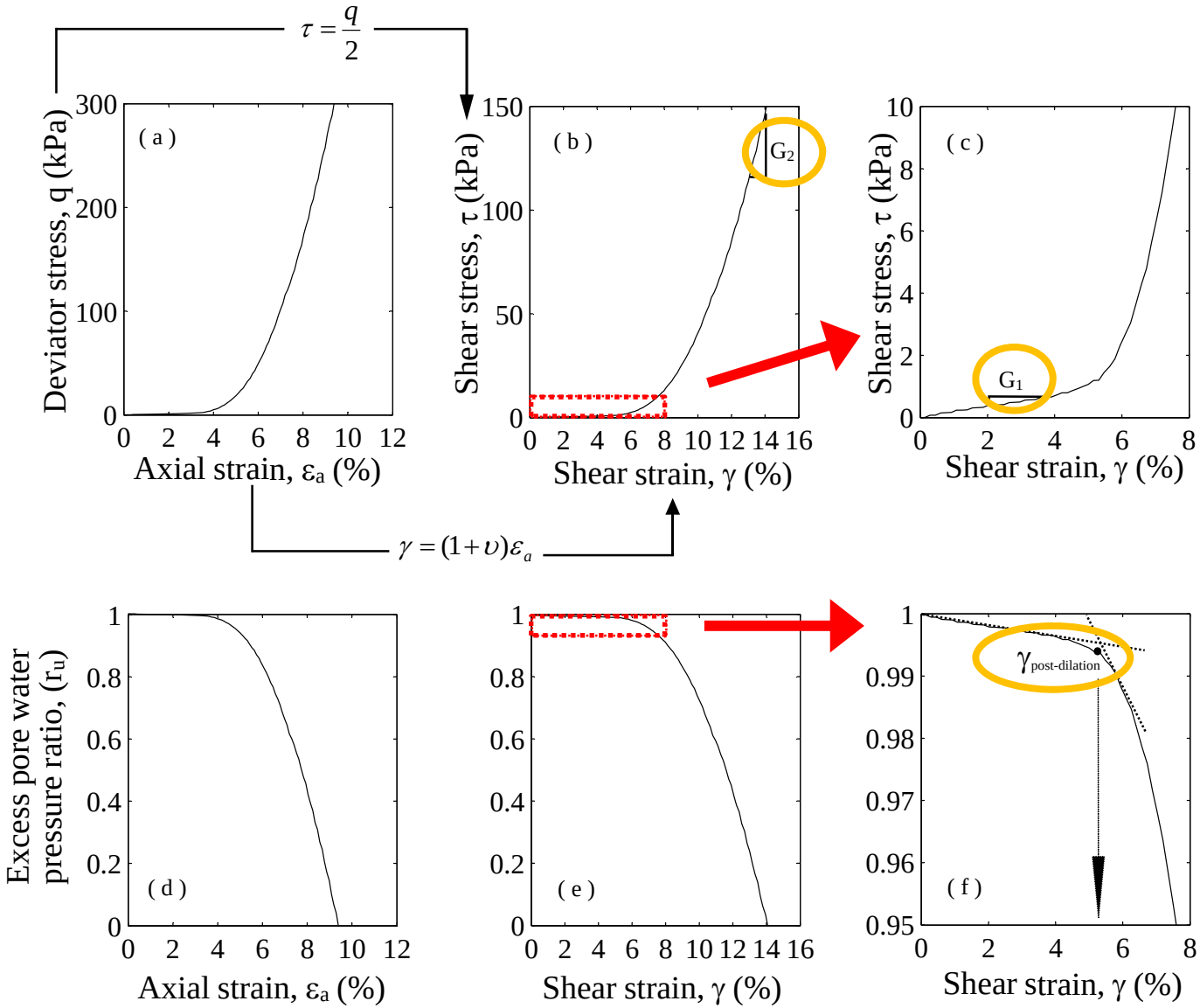
Bilinear model



Effect of D_r

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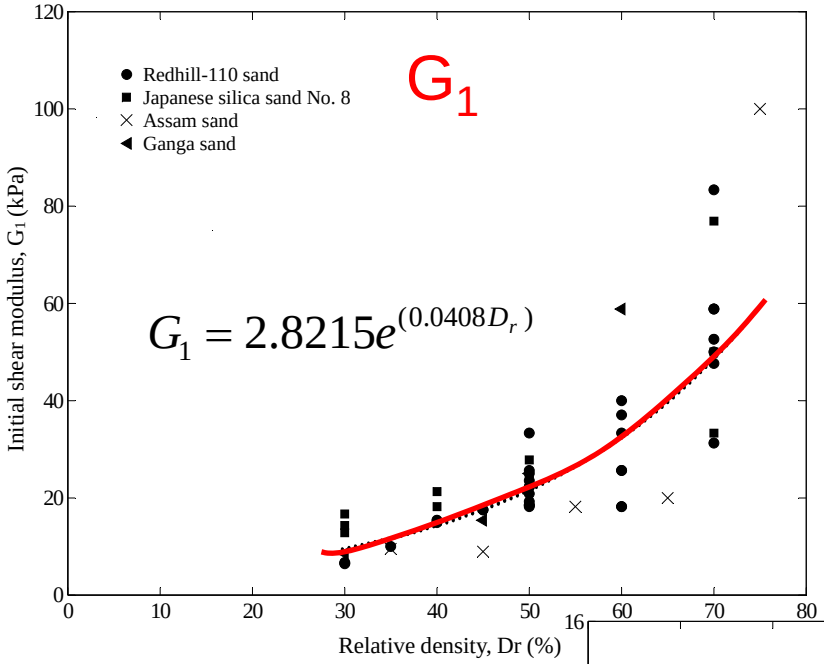

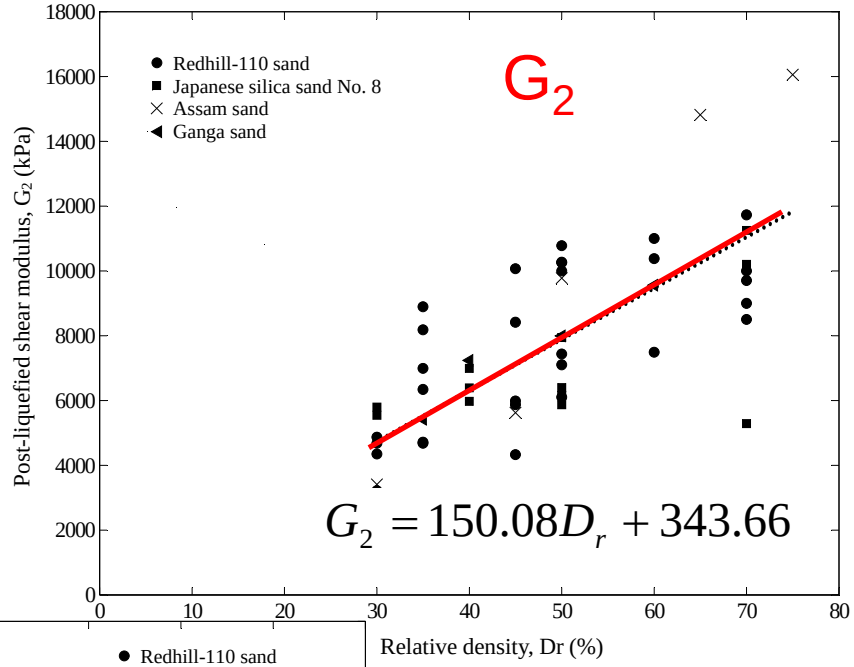

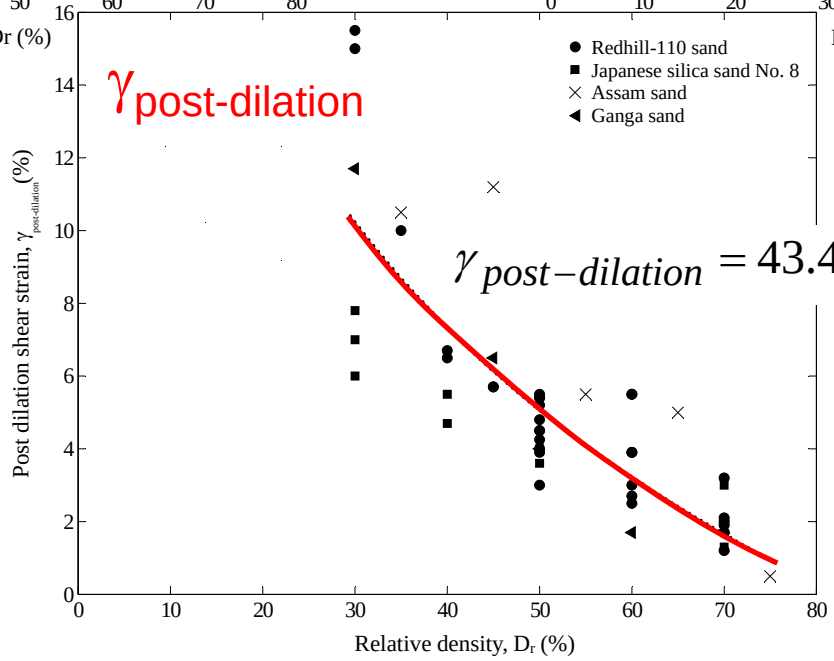

Effect of σ_c'

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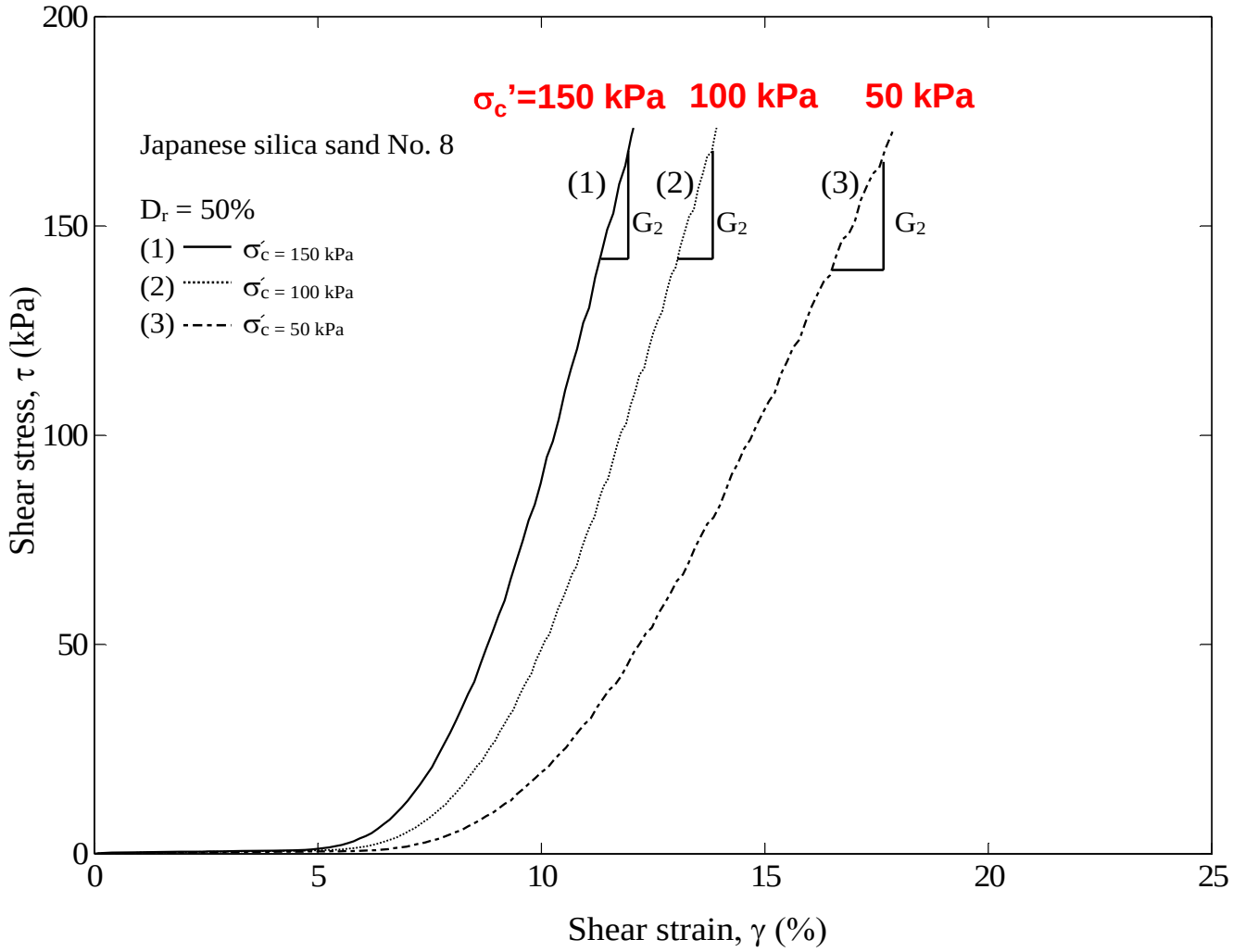
Japanese Silica Sand



Data too limited to make definite conclusions!

Natural Pumice sands

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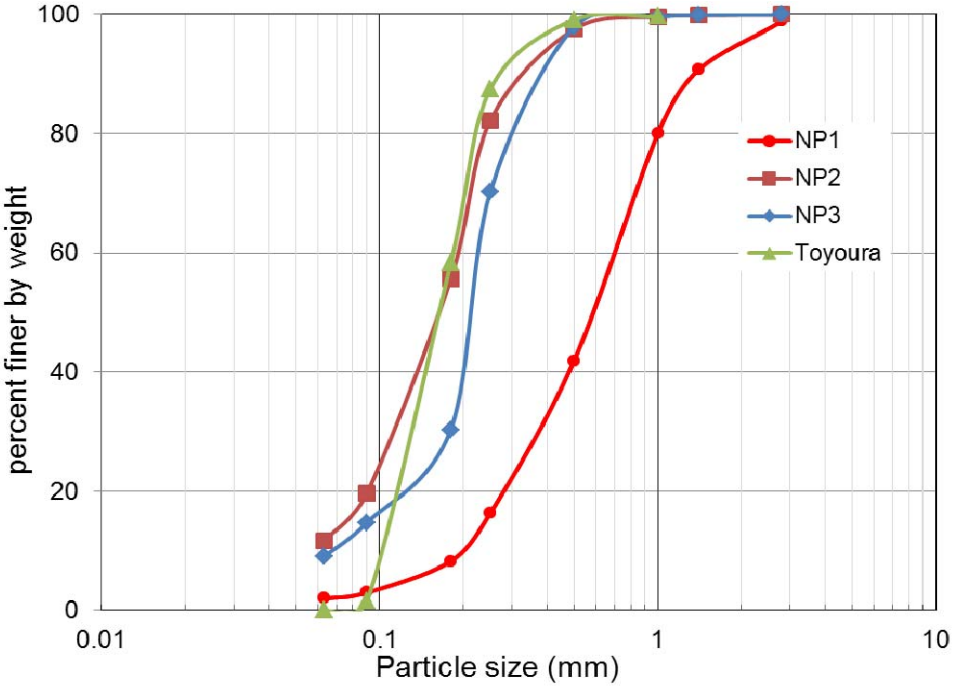

} Natural pumice deposits from 3 sites in Waikato (NZ)

Material	Specific gravity	Max. Void ratio	Min. void ratio
NP1	2.53	0.99	0.65
NP2	2.50	1.33	0.82
NP3	2.54	1.74	1.04
Toyoura sand	2.66	0.89	0.61

Grain characteristics

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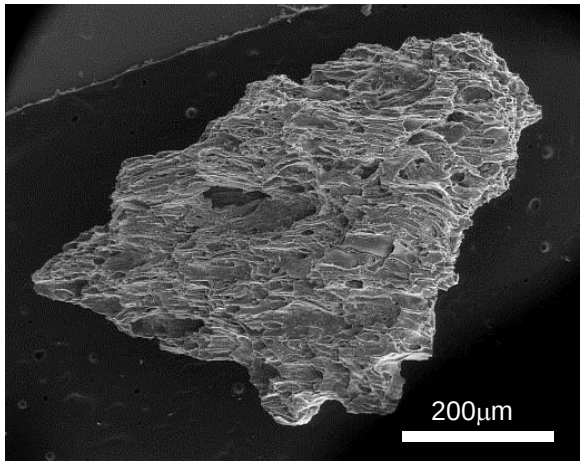
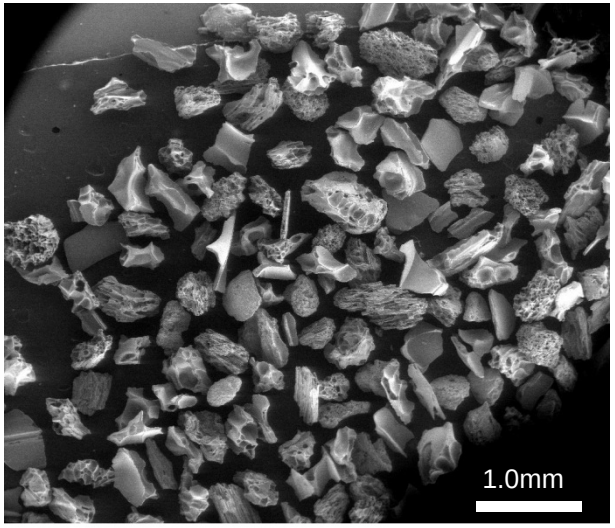
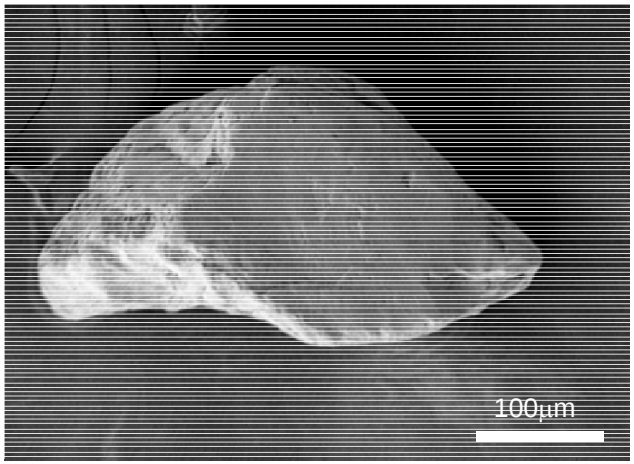
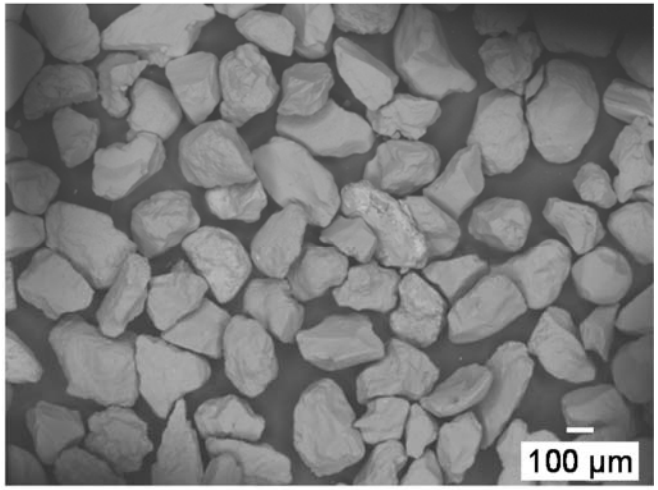
Pumice sand





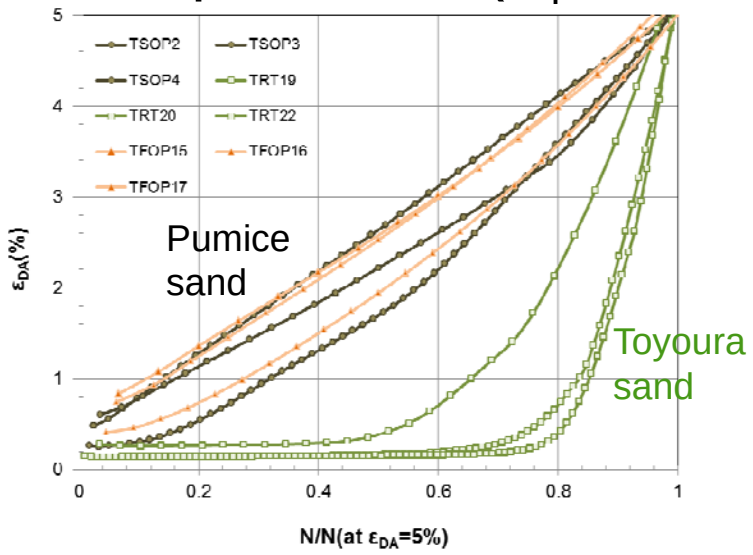
Toyoura sand

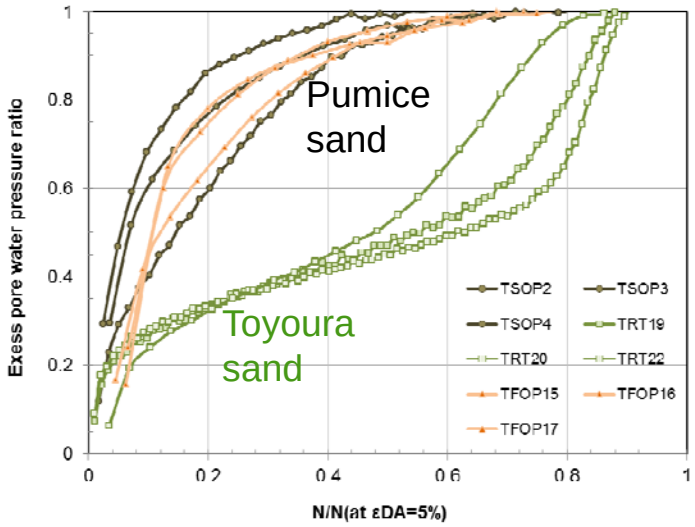




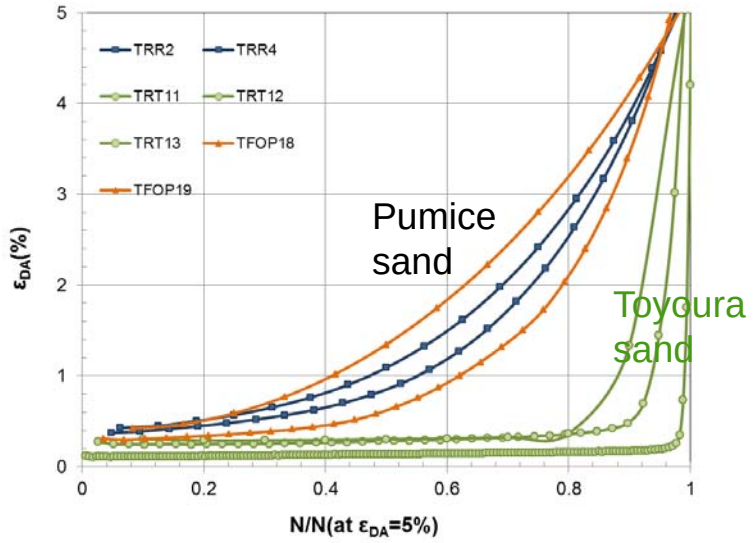
Undrained cyclic response

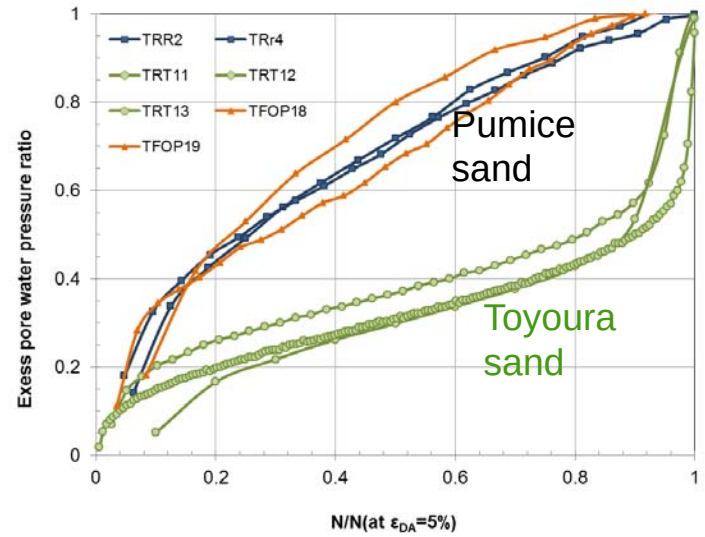
- Dense specimens (D_r=80-90%)





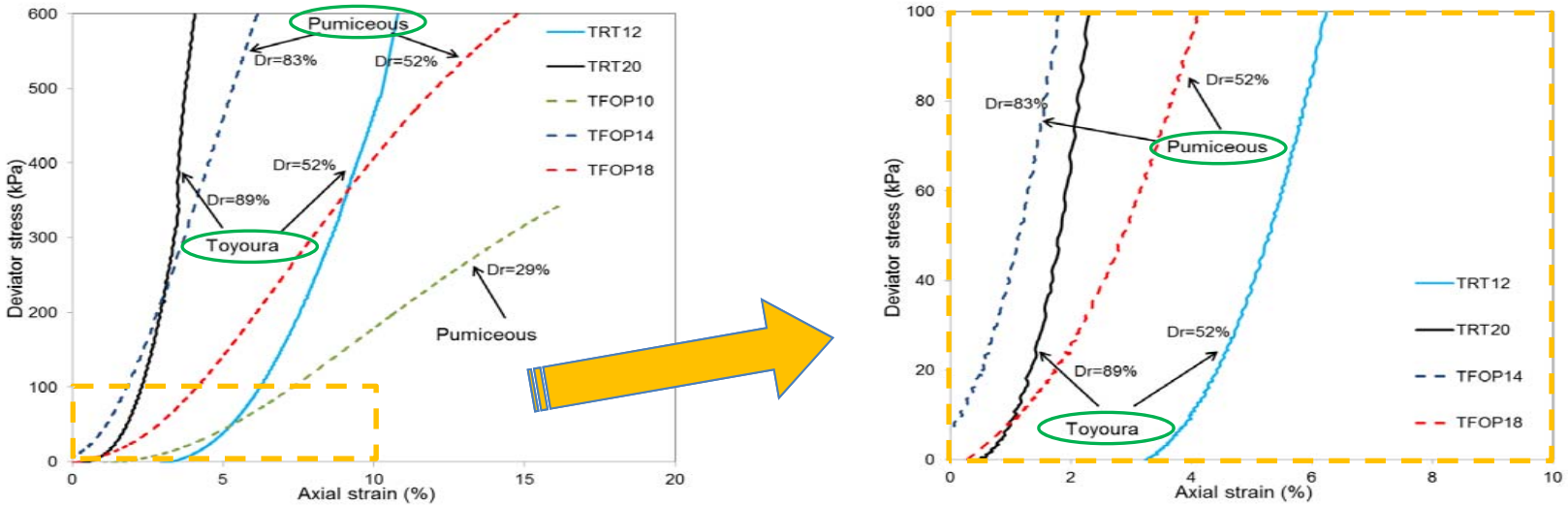
- Medium dense specimens (D_r=50-55%)



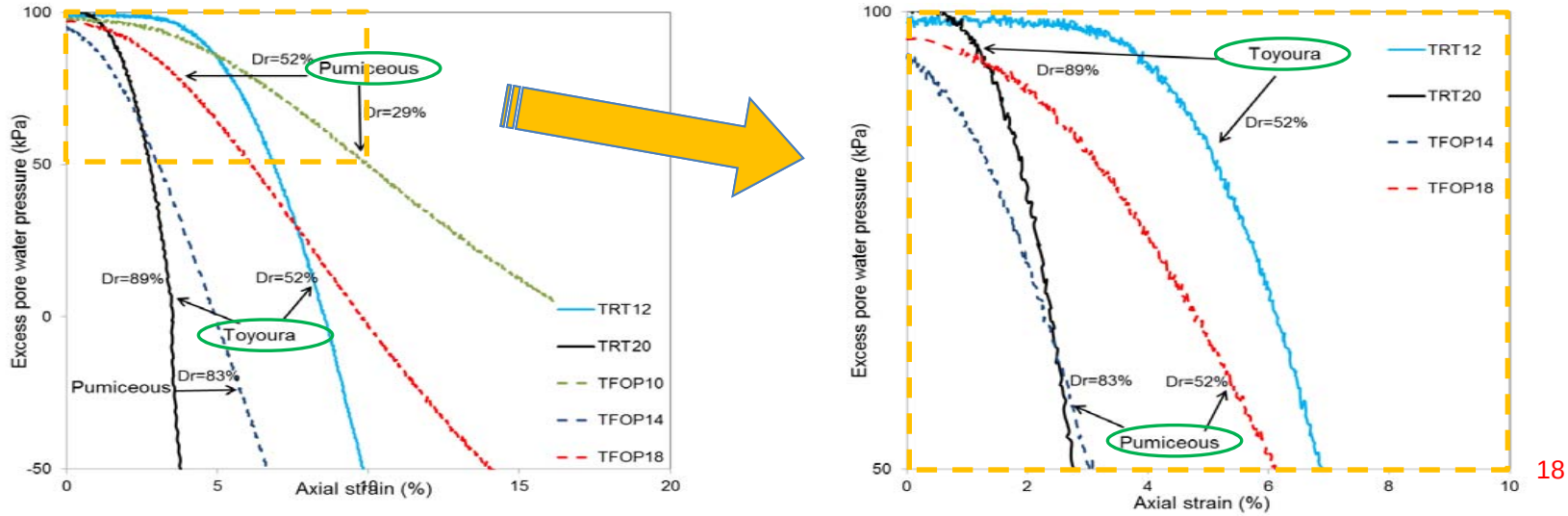


Post liquefaction behaviour

- Stress – strain behaviour



- Excess PWP – strain behaviour



Post liquefaction behaviour

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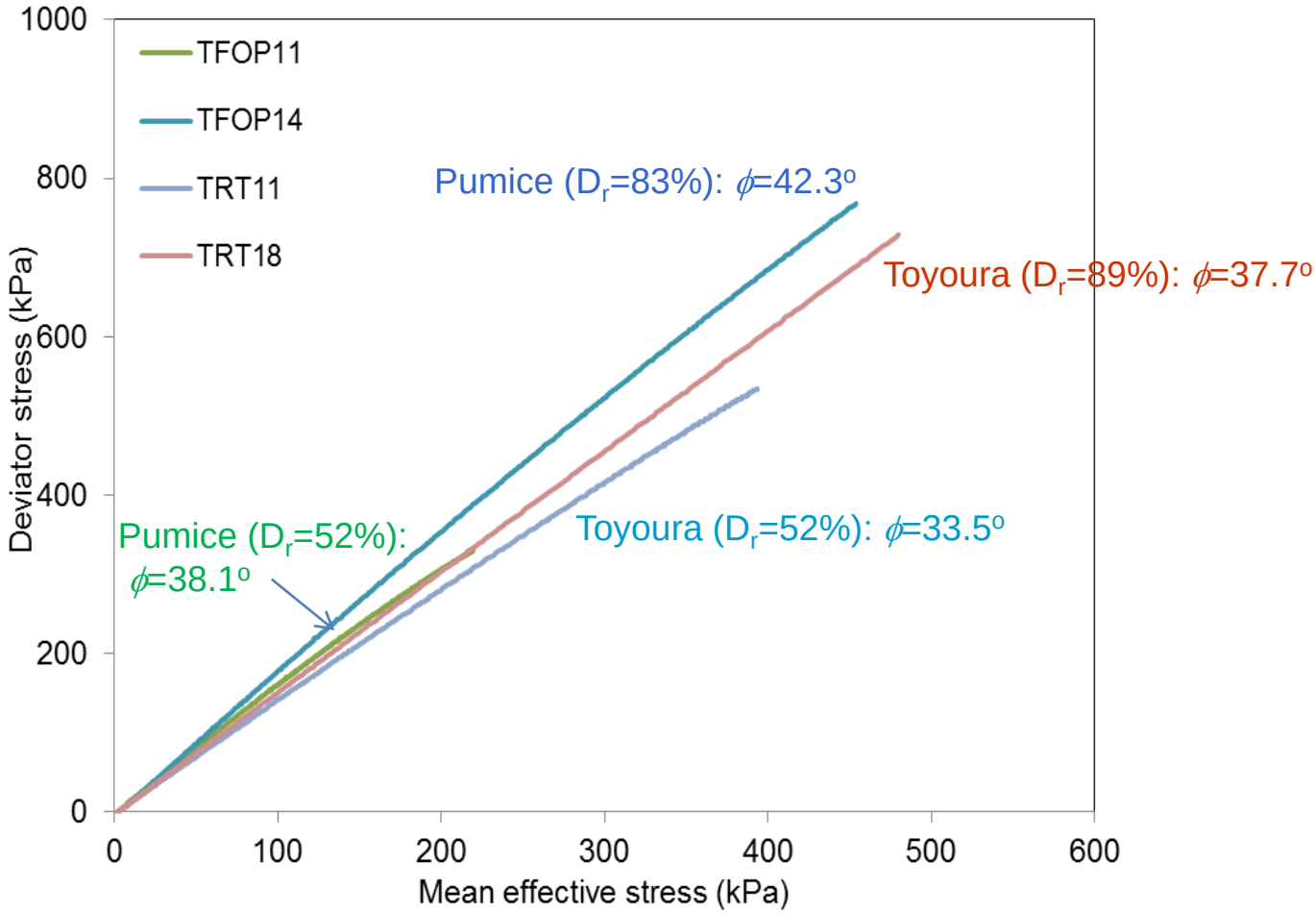
- Stress paths



Concluding Remarks

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- The stress-strain behaviour of liquefied sands can be modelled as bi-linear curve which is defined in terms of three parameters:
  - the initial shear modulus (G_1);
  - critical state shear modulus (G_2); and
  - post-dilation shear strain ($\gamma_{post\text{-}dilative}$)
- Each of these parameters is a function of the initial relative density of the sands. Thus, if the relative density of sand is estimated empirically (e.g. from penetration resistance or any other means), the three post-liquefaction parameters can be approximated and the post-liquefaction behaviour can be defined.
- Crushable pumice sands appear not to follow the behaviour of hard-grained sands.