College of Engineering, Nihon University
日本大学工学部

International workshop on the soil element test for liquefaction analysis

(pre-LEAP event at March 13, 2019.
Venue:M804, Kansai University-Takatuski Muse campus)

A proposal of new liquefaction test scheme

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Contents

Background

- Undrained cyclic shear test to obtain Cyclic resistance ratio(CRR) are frequently conducted in practice.

- CRR is a main target to determine parameters for liquefaction analysis.

- Shortcoming of CRR based parameter determination are
  - CRR is mainly an index for fatigue fracture
  - It is difficult to get the information about
    - process to initial liquefaction
    - long shaking duration history
    - large residual deformation (settlement and larger shear strain)

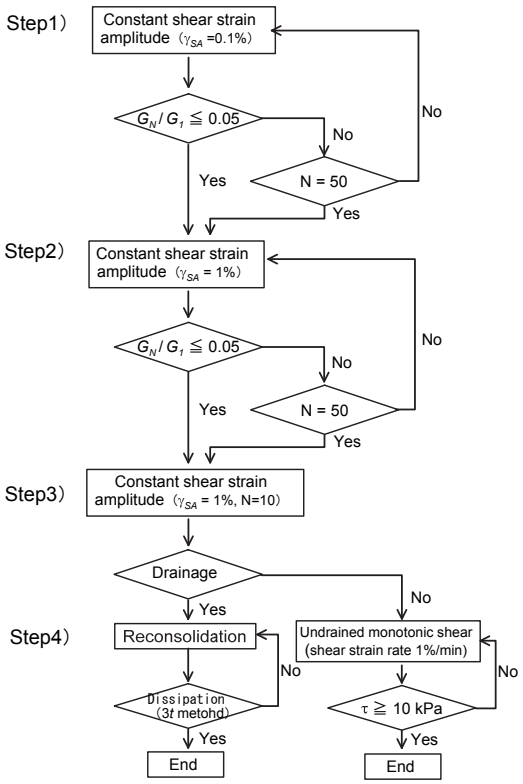
- At least 3 or 4 specimens are necessary to determine CRR

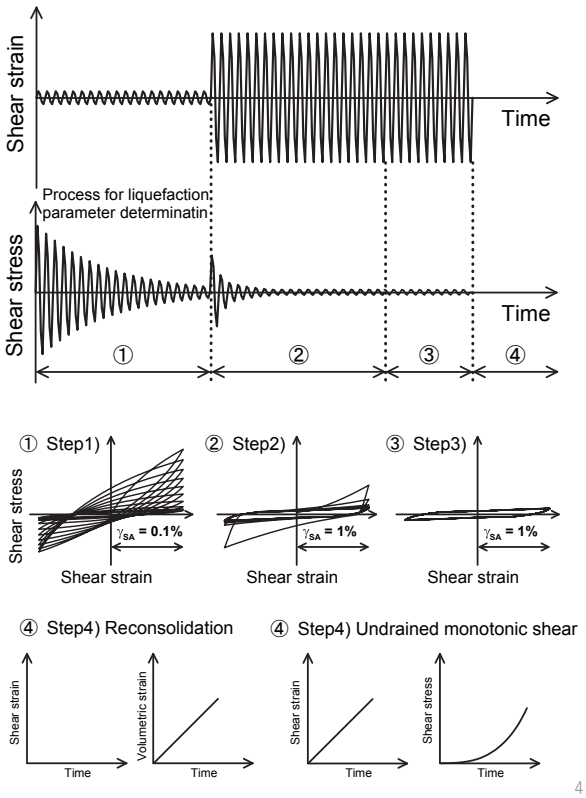
Object of tests

Element test consisting of 4 steps for one specimen is proposed to estimate

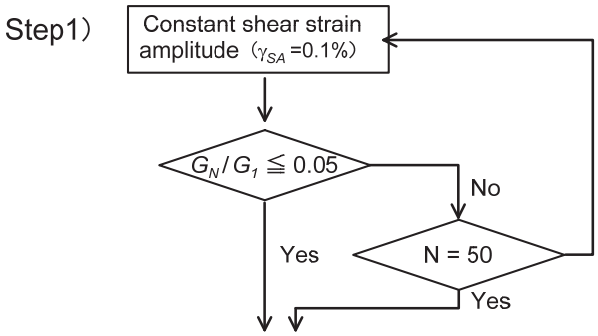
- The process to the initial liquefaction (**Step1**)
  - determine liquefaction parameter
- The effect of larger cyclic shear strain history (**Step2**)
- The effect of further cyclic shear following liquefaction (**Step3**)
- The Residual deformation (reconsolidation or undrained shear strain) (**Step 4**)

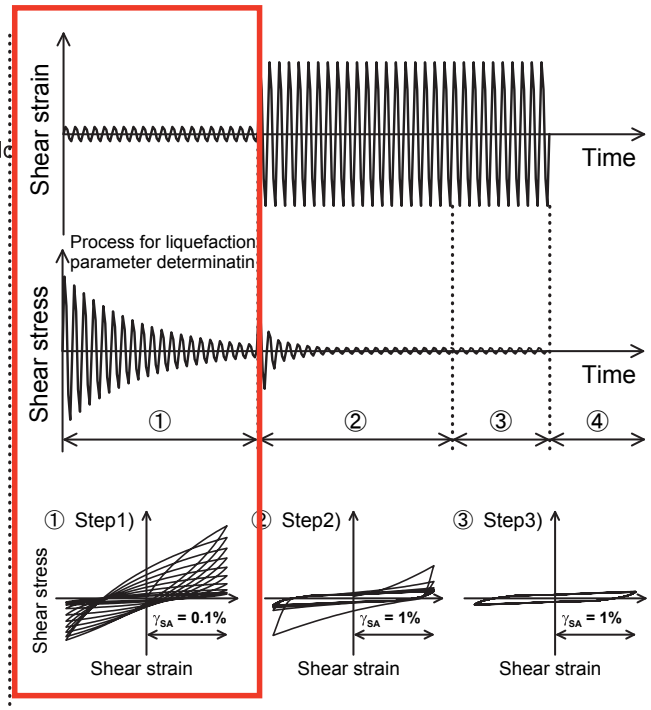
Outline of tests (4 steps)



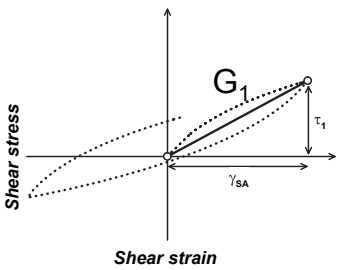


Outline of tests (Step 1)



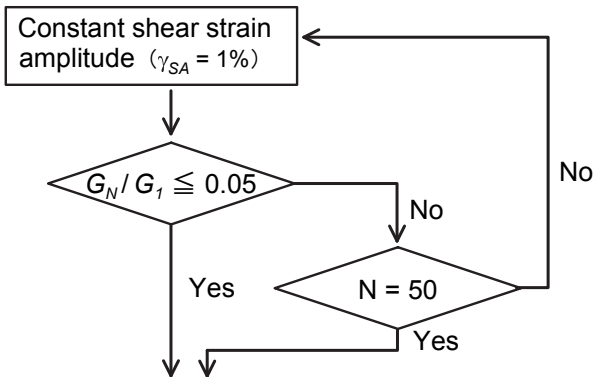


Undrained cyclic shear is conducted with constant shear strain amplitude of γ_{SA} 0.1%

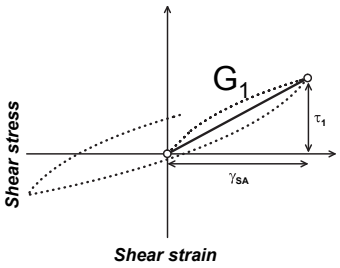


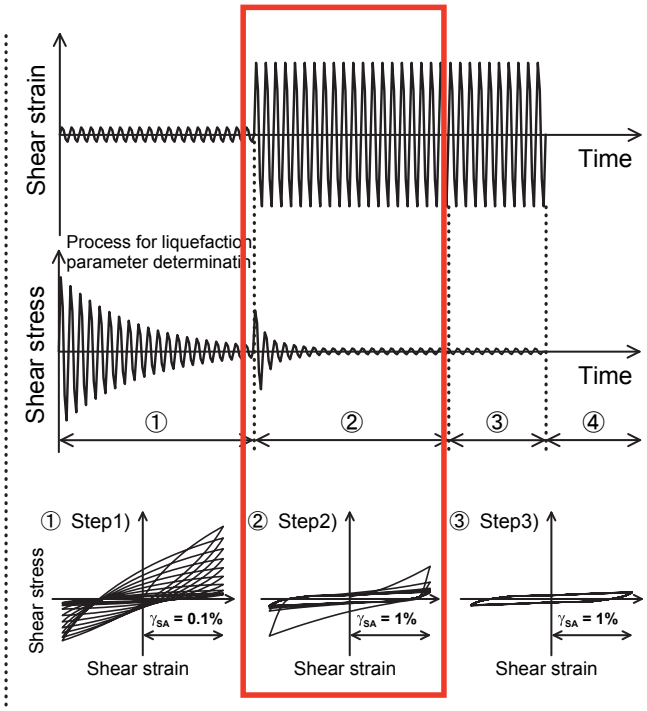
Step terminates when the ratio G_N / G_1 is less than to 0.05 G_1 or N=50cycles
(G_N: secant shear modulus of N cycles)

Outline of tests (Step 2)



Undrained cyclic shear is conducted with constant shear strain amplitude of γ_{SA} 1%





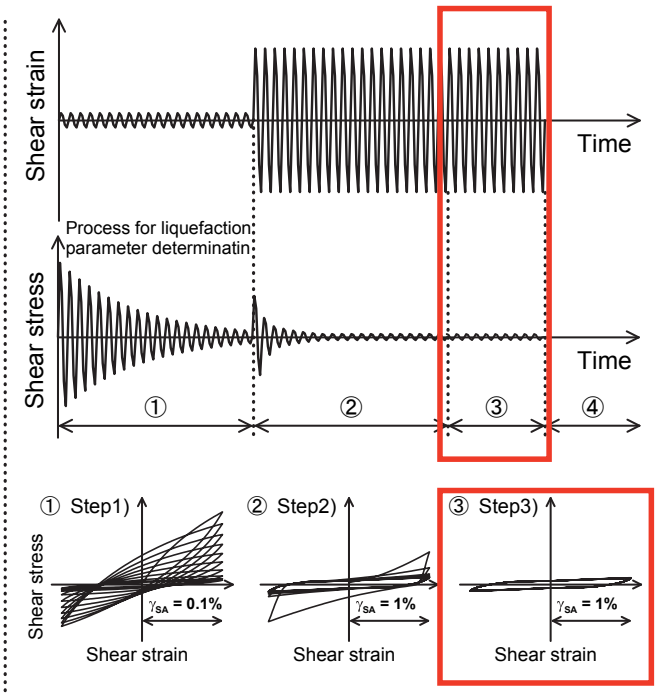
Step terminates when the ratio G_N / G_1 is less than to 0.05 G_1 or N=50cycles

Outline of tests (Step 3)

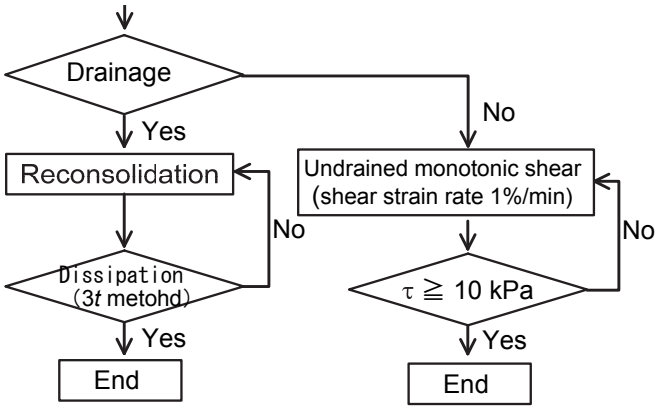
Constant shear strain amplitude（γ_{SA} = 1%, N=10）

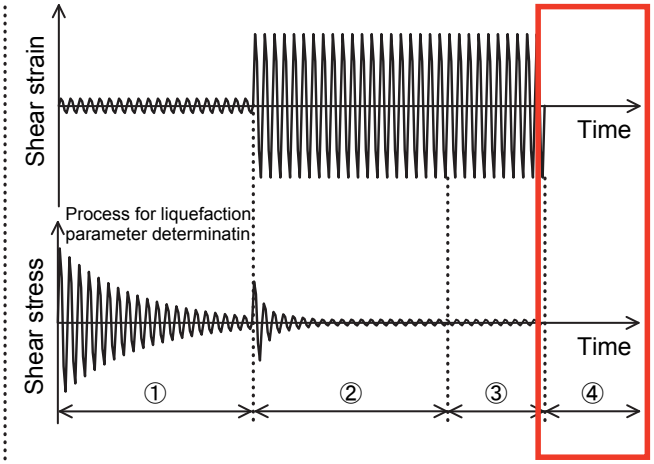
↓

Further Undrained cyclic shear (N=10) is conducted with constant shear strain amplitude of γ_{SA} 1%

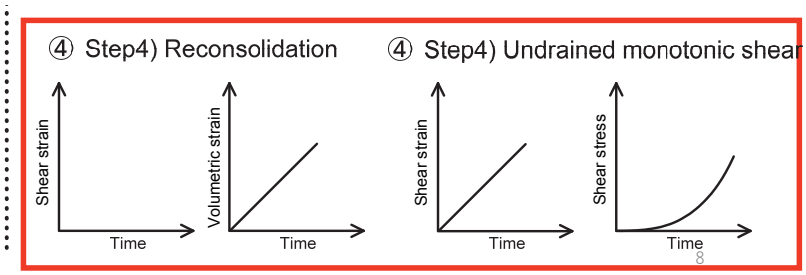


Outline of tests (Step 4)

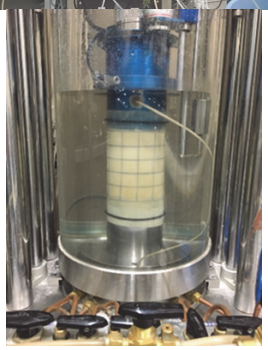


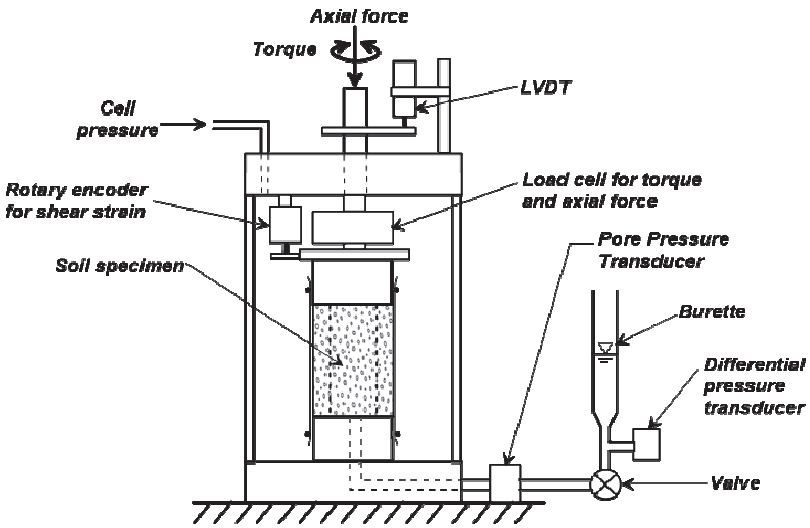


In case of drainage
Reconsolidation test is conducted to obtain volumetric strain
Otherwise, Undrained monotonic shear loading is conducted to obtain residual shear strain following liquefaction



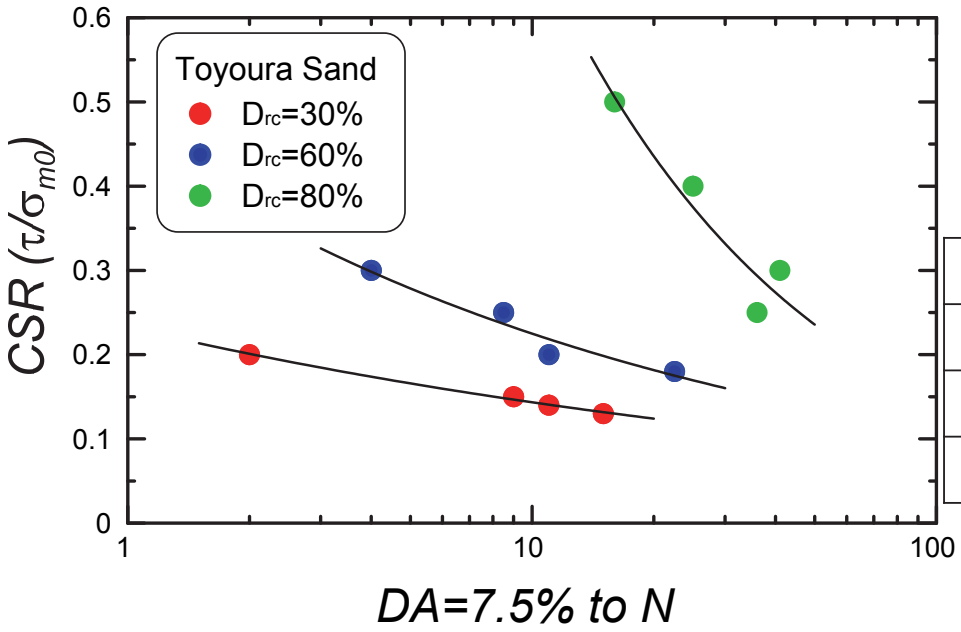
Equipment: Hollow cylinder torsion test





Torque and axial force is applied to control the shear and axial stress/strain
Torque and axial force is measures by Load cell.
Shear strain is measured by rotary encoder.

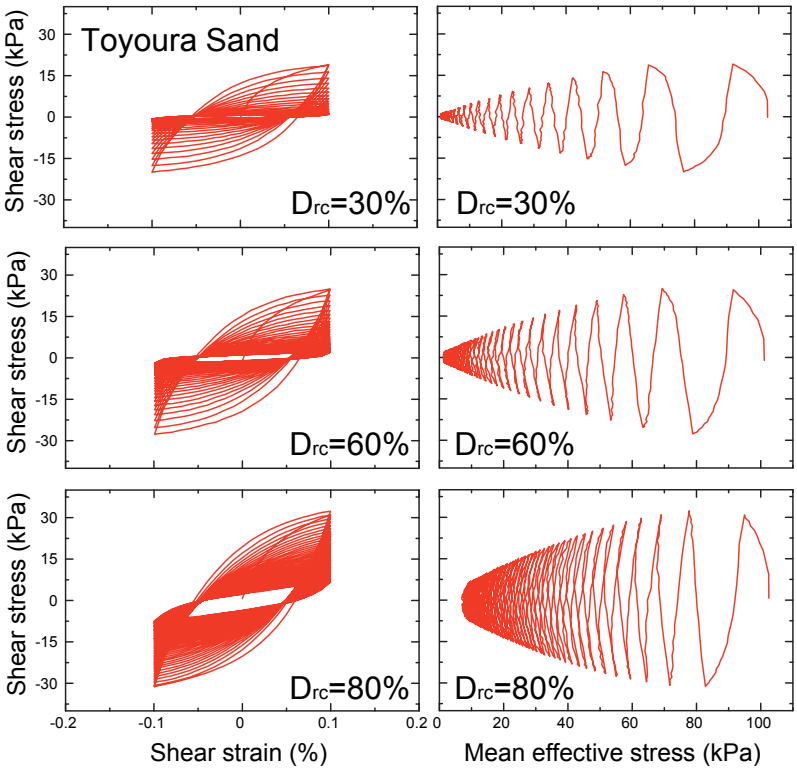
Test result (CSR-N)



D_{rc}(%)	$CRR_{N=20}$
30	0.13
60	0.18
80	0.43

Stress controlled test was conducted to obtain CSR-N relation ship for loose, medium dense and dense Toyoura sand. Liquefaction is defined as double amplitude of 7.5 %. CRR of N=20 is summarized.

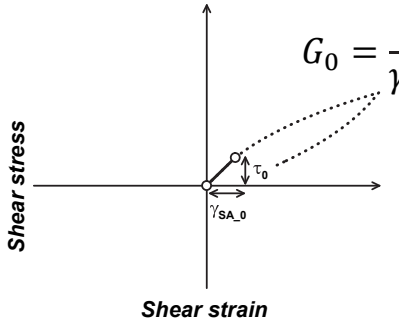
Test results (Step 1)

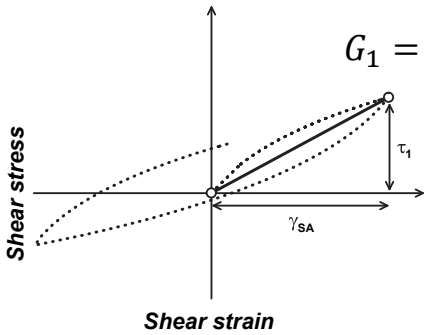


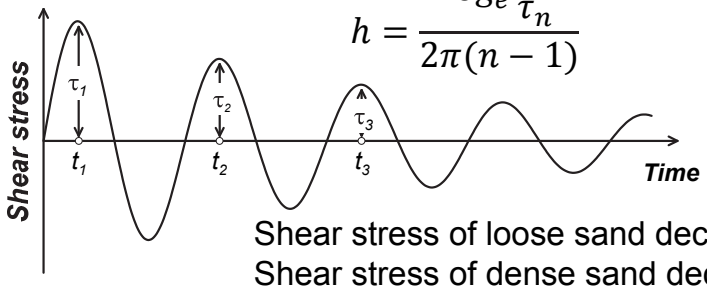
Shear stress decreases as mean effective stress decreases. Loose and medium dense sand liquefied and shear stress is close to zero during cyclic loading. Dense sand did not liquefy during 50, cycles shear resistance was observed.

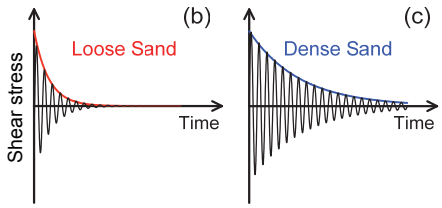
Index for parameter fitting in Step1

- G_0 : Initial shear modulus of virgin loading
- G_1 : Secant shear modulus of virgin loading
- h : Attenuation factor of shear stress amplitude





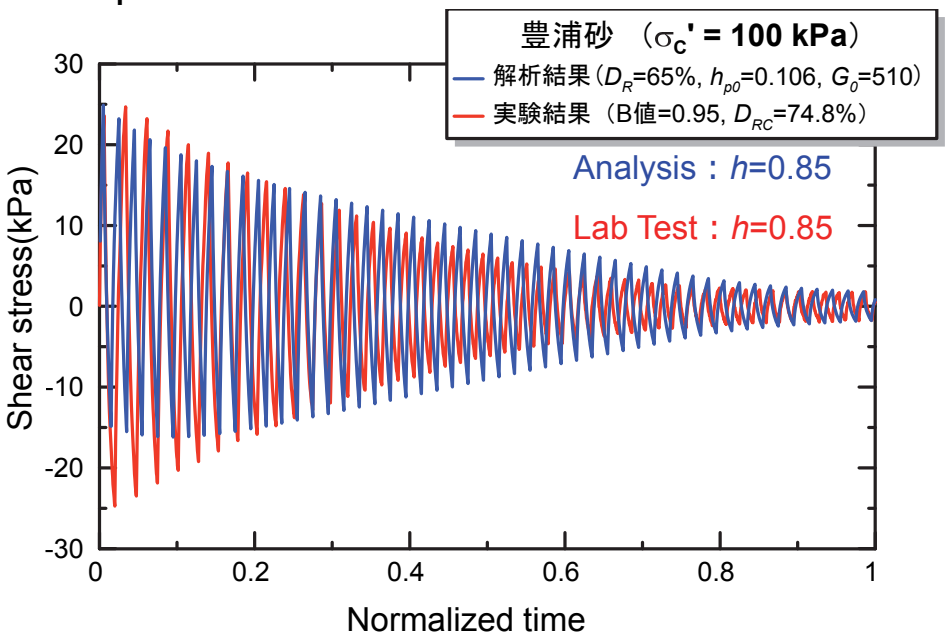




Shear stress of loose sand decreases rapidly.
Shear stress of dense sand decreases gradually

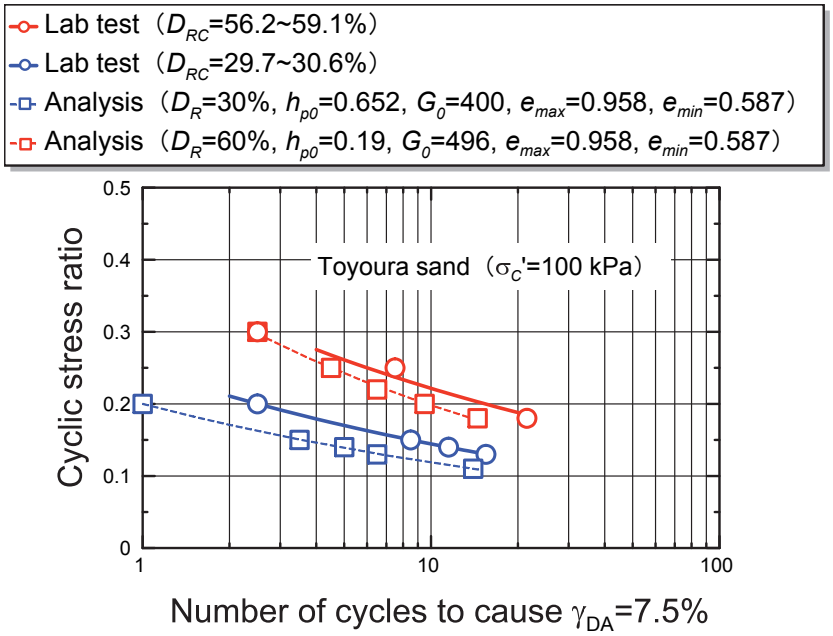
Example of parameter fitting result

Parameter determined considering index (G0, G1, h) in the Step1.



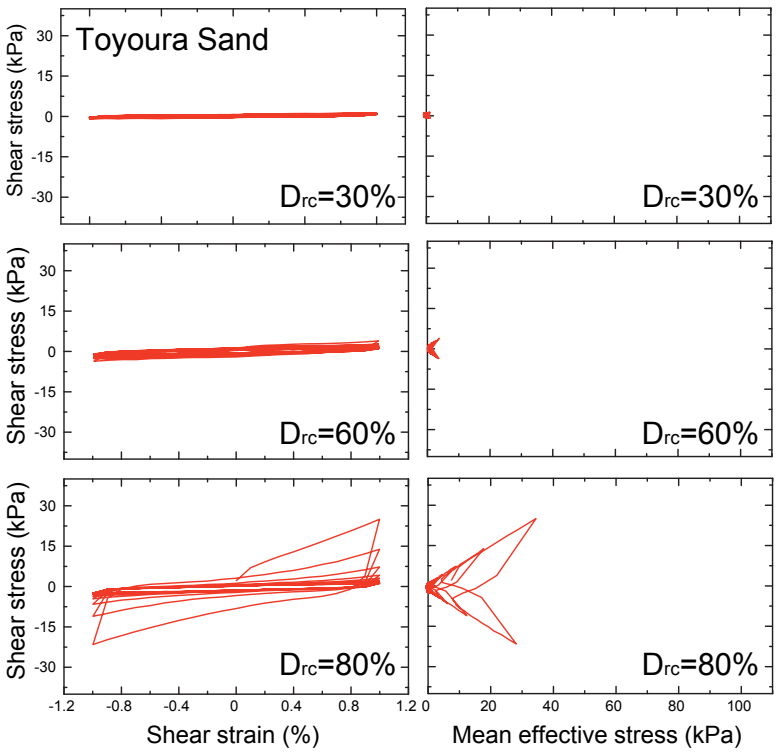
h was compared to confirm the shear stress attenuation behavior between lab test and analysis

CSR-N relation of lab test and analysis



CSR-N relation is simulated by FLAC (PM4sand) with the parameter determined by Step 1 test results.
CSR-N curve of analysis is almost same as Lab test

Test results (Step 2)



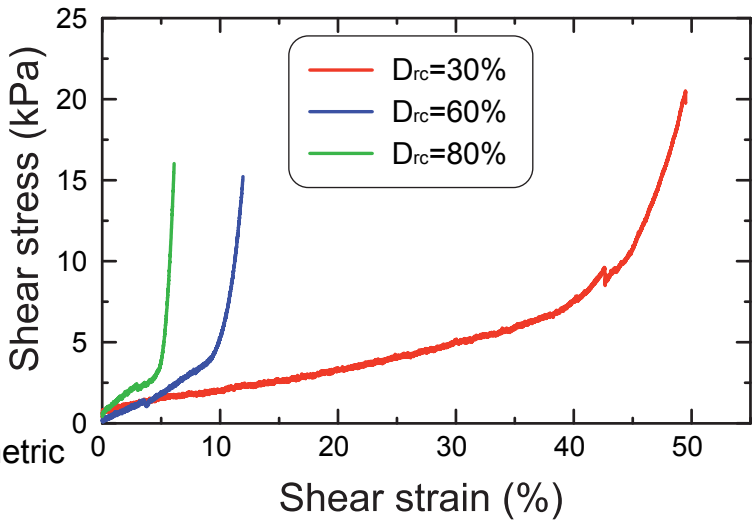
Larger shear strain (γ_{SA} 1%) is appled following Step1. Shear stress recovery due to cyclic mobility was observed in dense sand. No shear stress recovery observed in loose sand.

Test results (Step 4)

Reconsolidation

D_{rc}(%)	ε_v (%)
30	5.90
60	2.22
80	1.72

Undrained monotonic shear



In reconsolidation test, 5.9% volumetric strain was observed in loose sand.

Undrained monotonic shear test, 45 % of shear strain was observed in loose sand as shear stress reached 10kPa.