

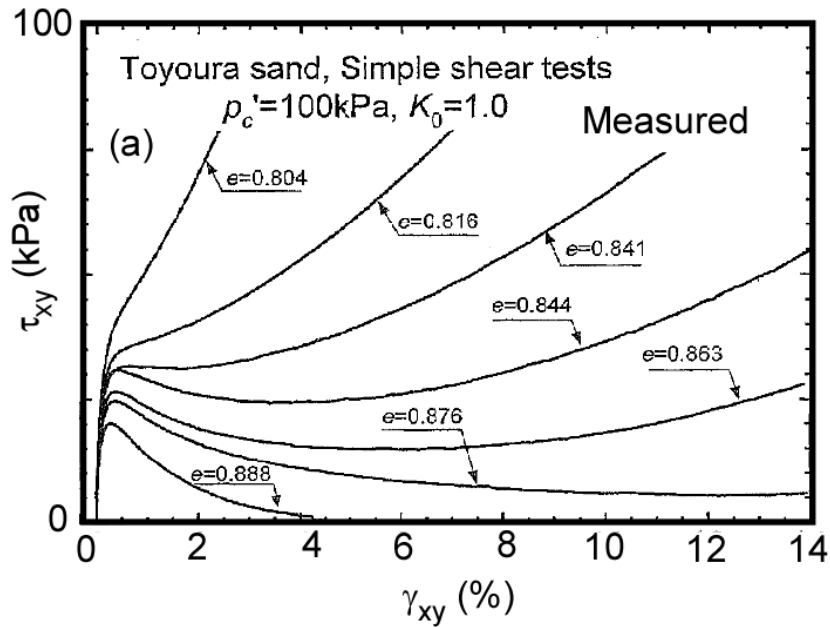
Paths forward for assessing the effects of liquefaction

Disaster Prevention Research Institute

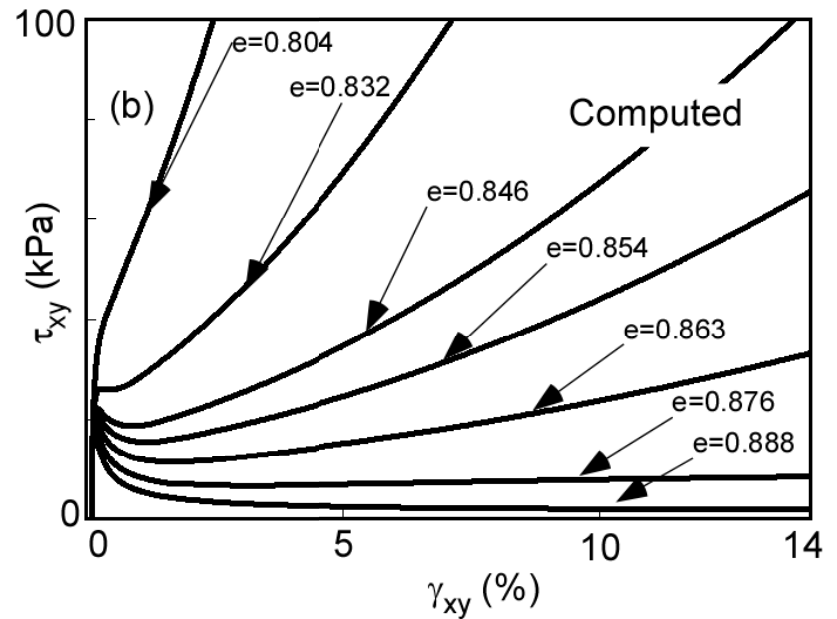
Kyoto University

Susumu Iai

Undrained monotonic shear

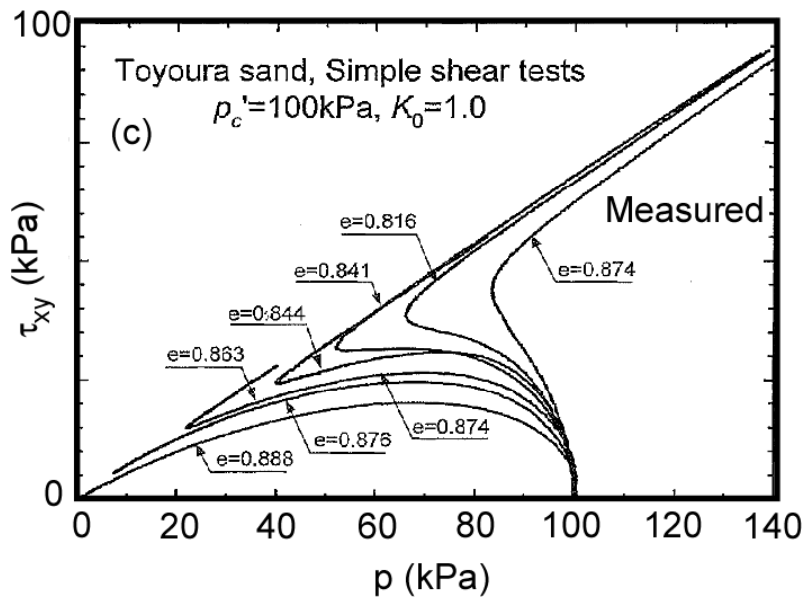


Yoshimine et al (1998),

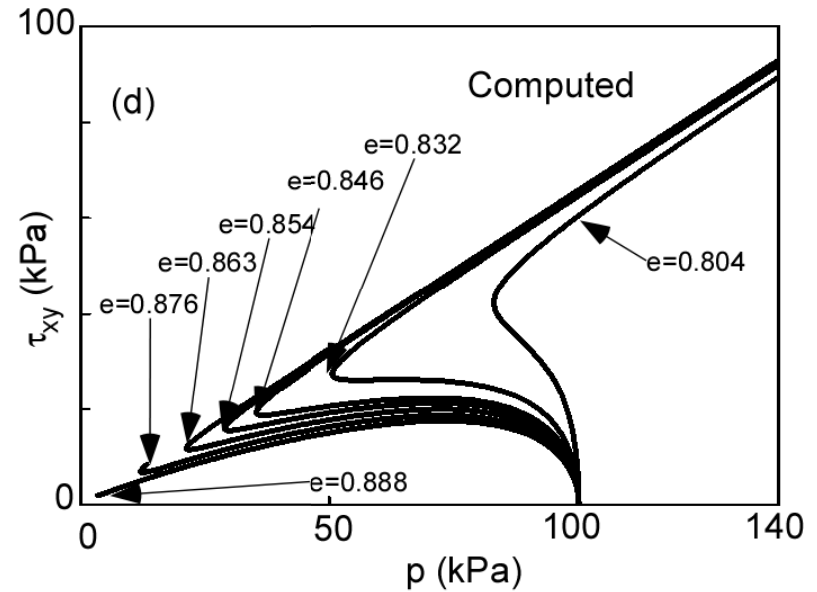


lai et al (2011)

Stress path undrained monotonic shear

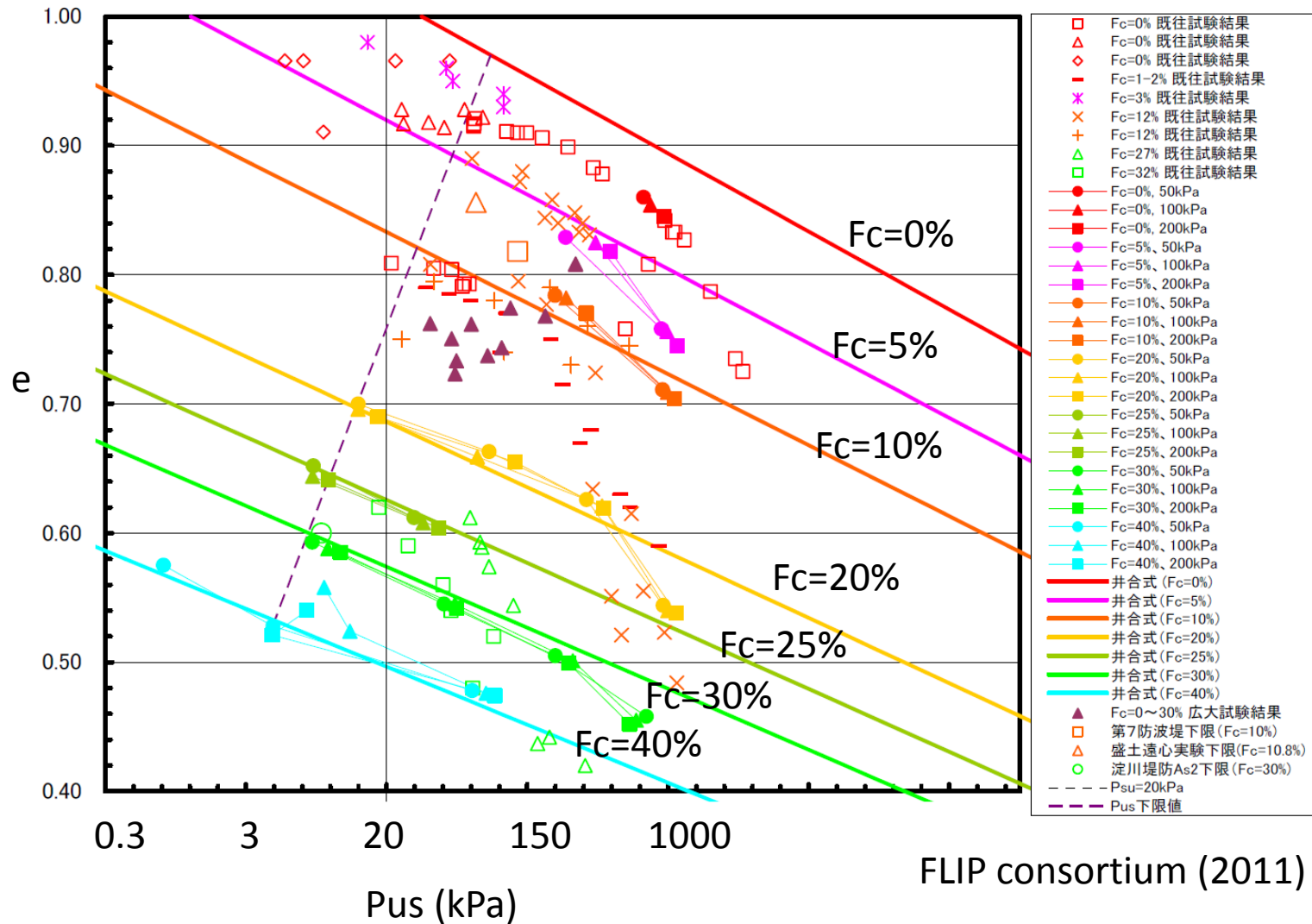


Yoshimine et al (1998),



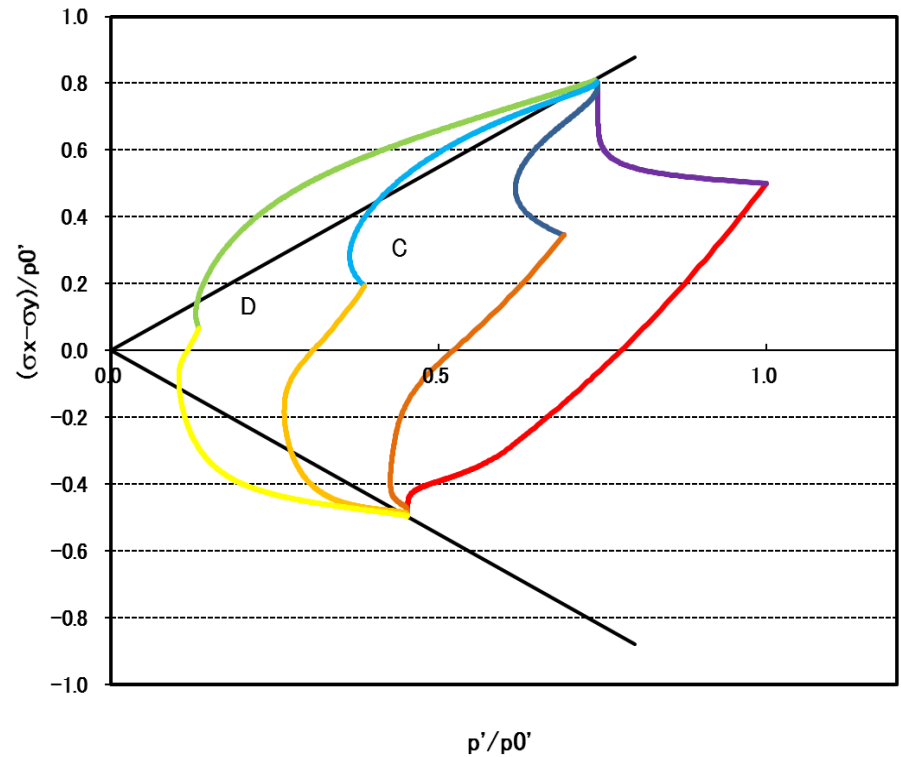
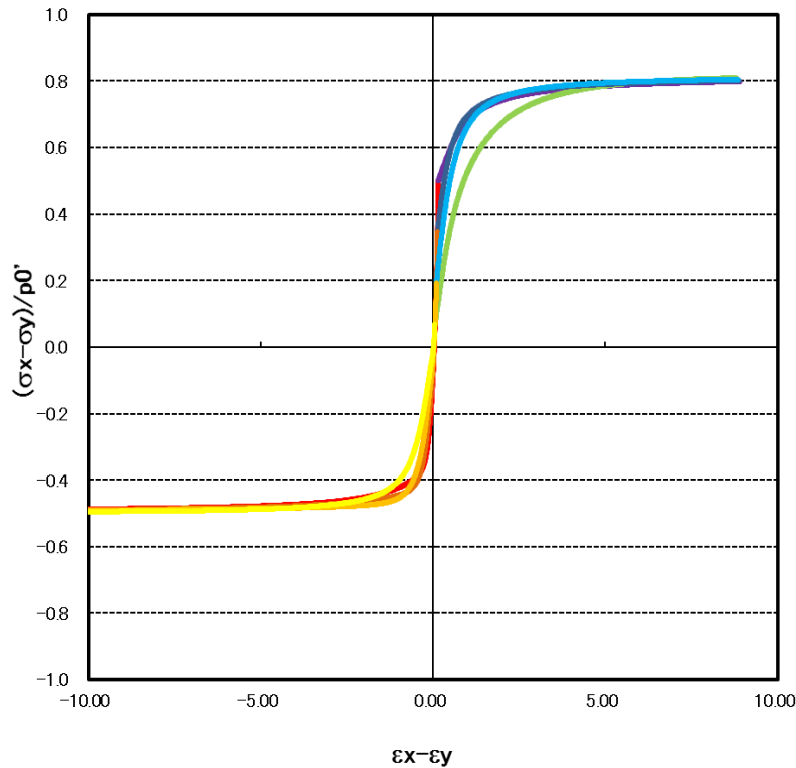
lai et al (2011)

Steady state: e-ln(P_{us}) relation



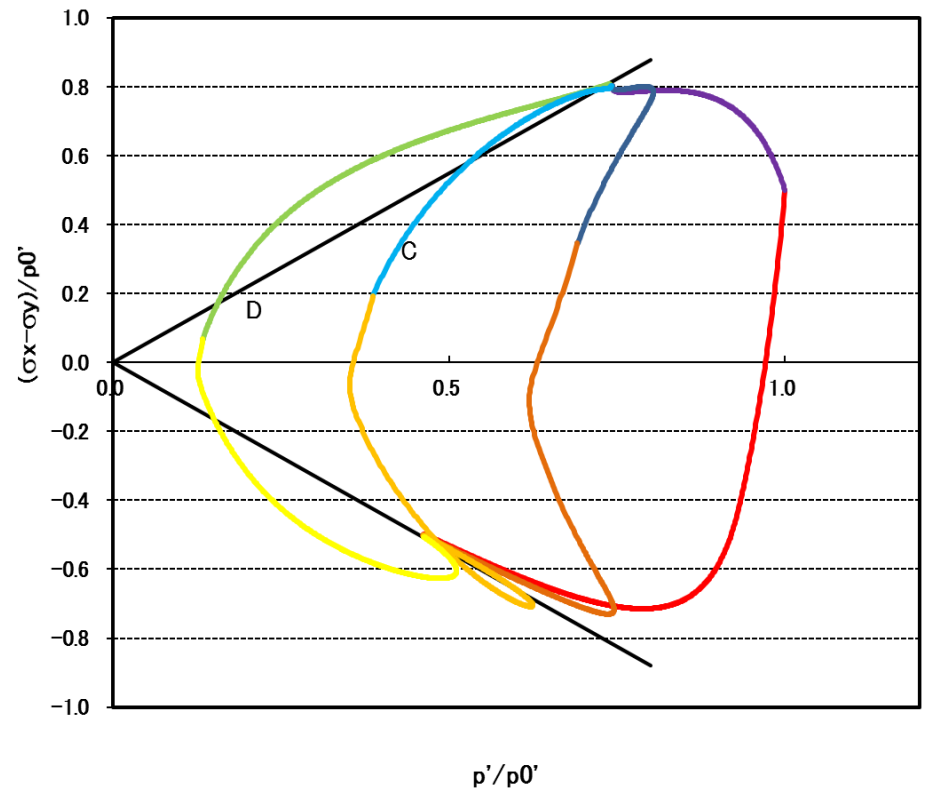
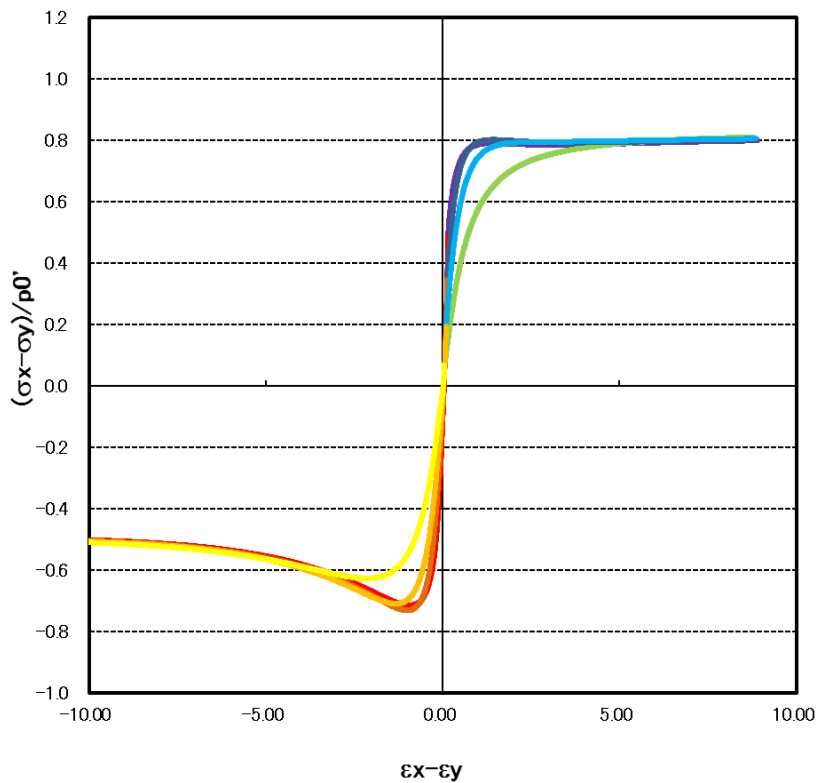
Effect of initial shear (stress induced anisotropy)

$$r_{\varepsilon_d^c} = 0.85, \Lambda = 0.544$$

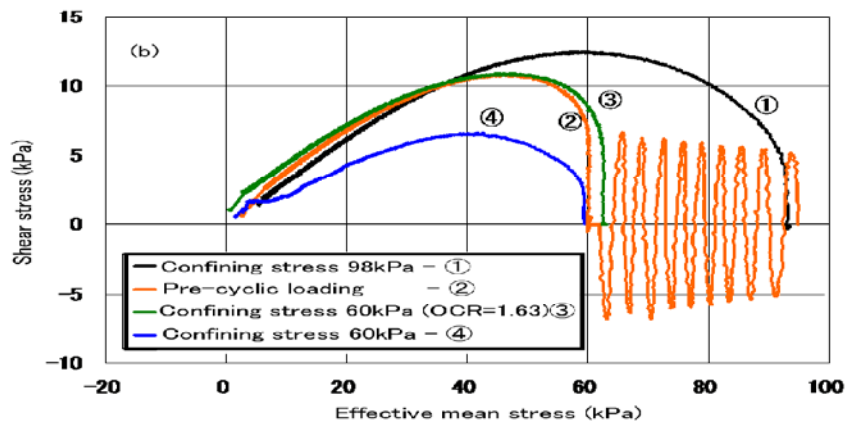
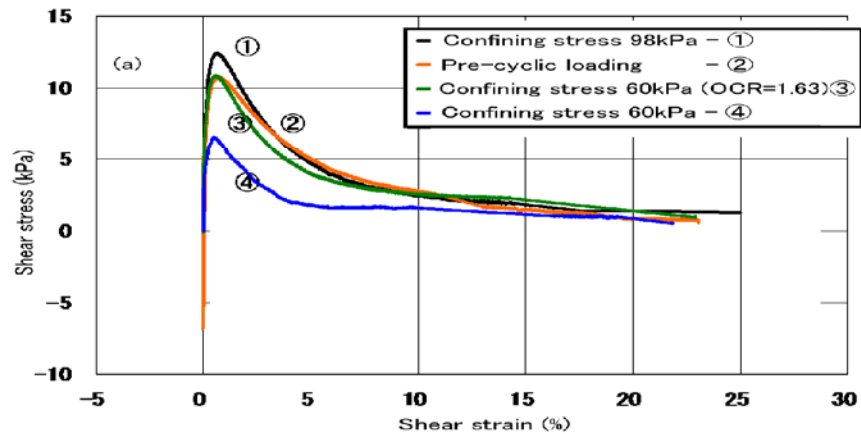


K0=0.6

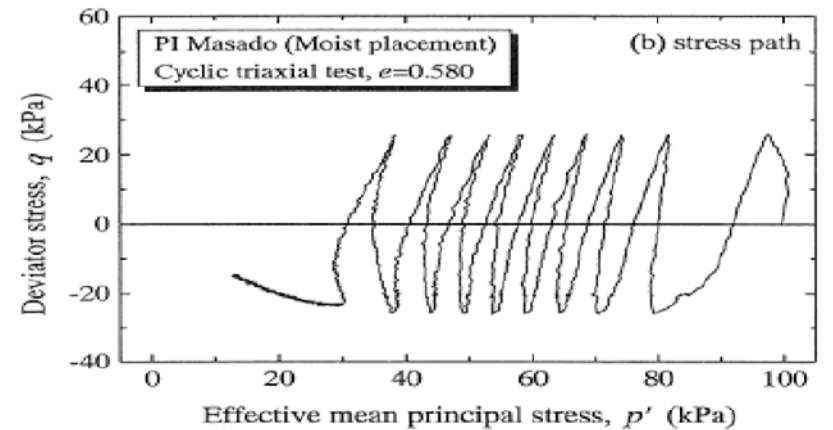
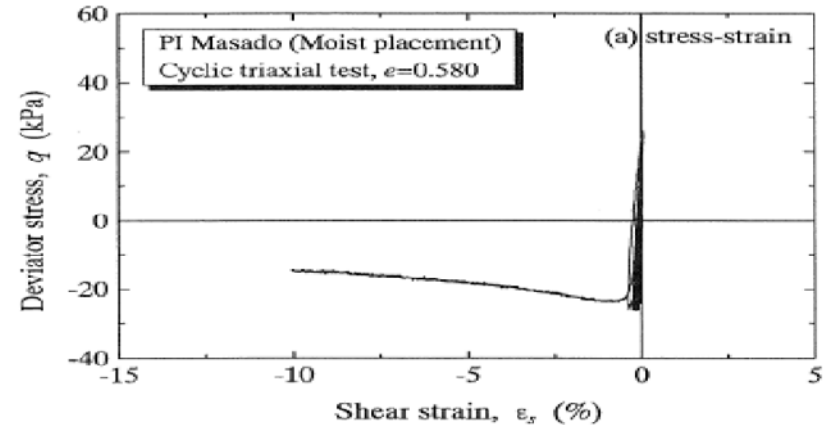
$$r_{\varepsilon_d^c} = 0.085, \Lambda = 0.544$$



Combination of cyclic shear and steady state



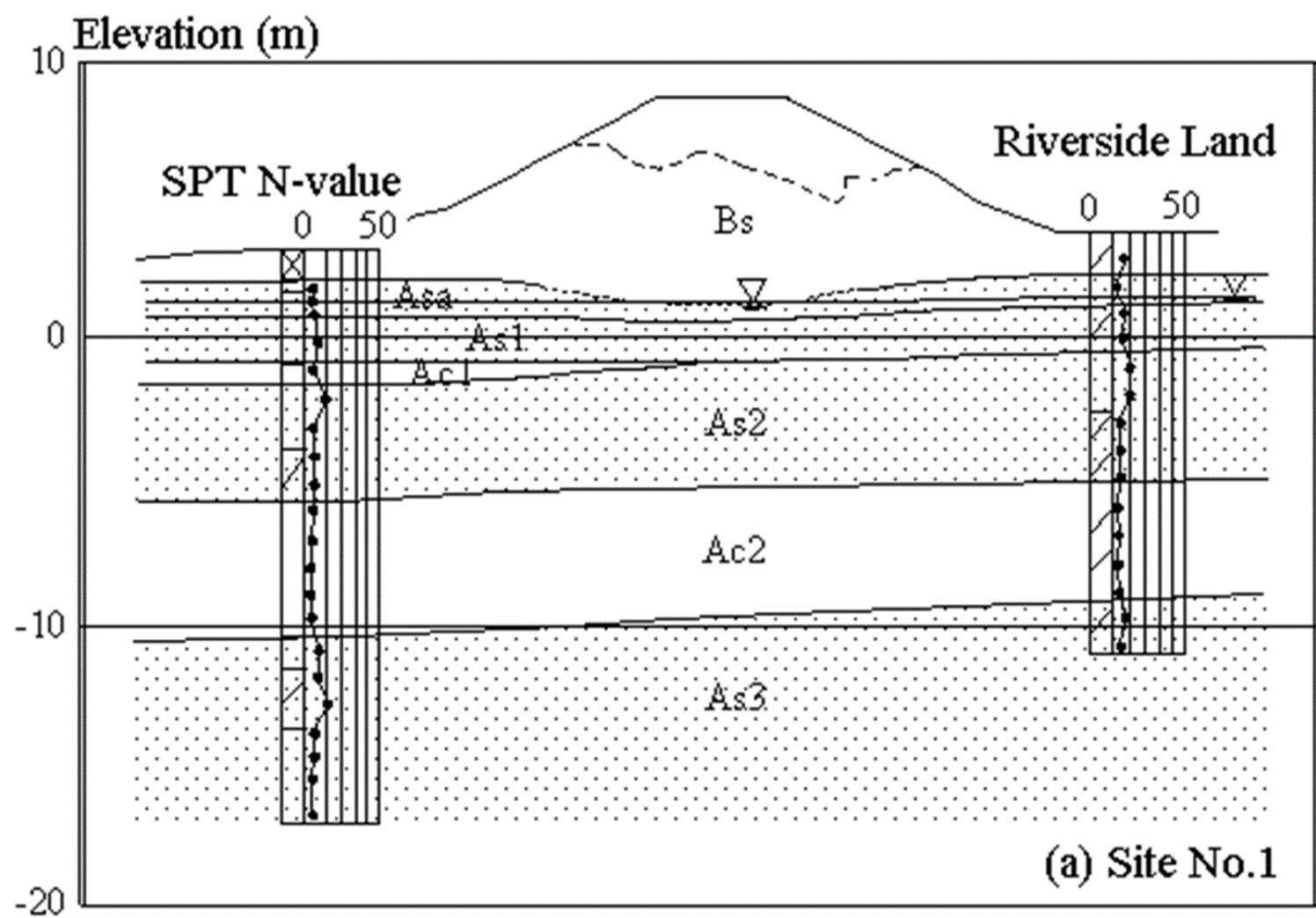
Ichii et al (2010)



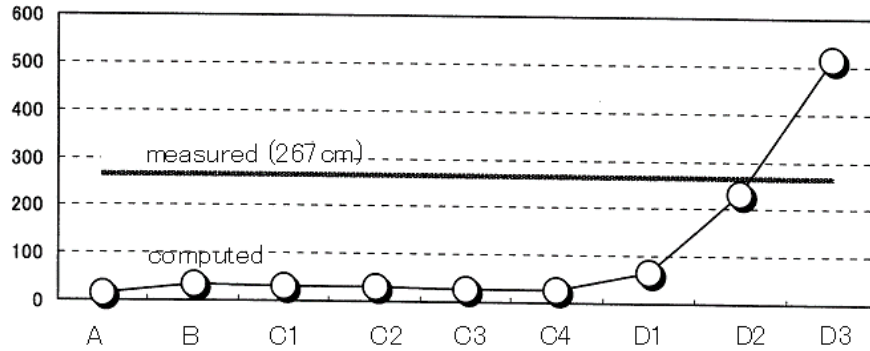
Toyota et al (2004)

Shiribeshi-Toshibetsu river, Hokkaido, Japan, 1993 Hokkaido-Nansei-oki earthquake



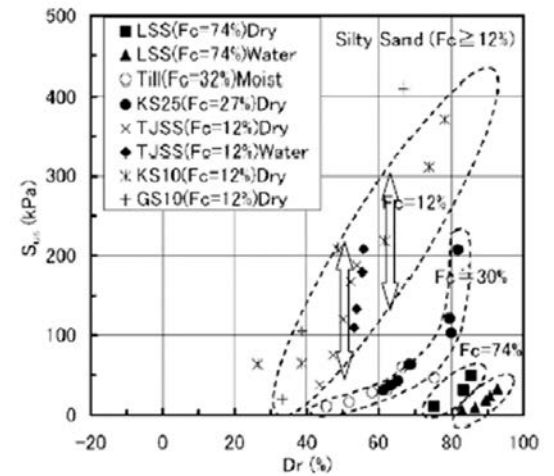
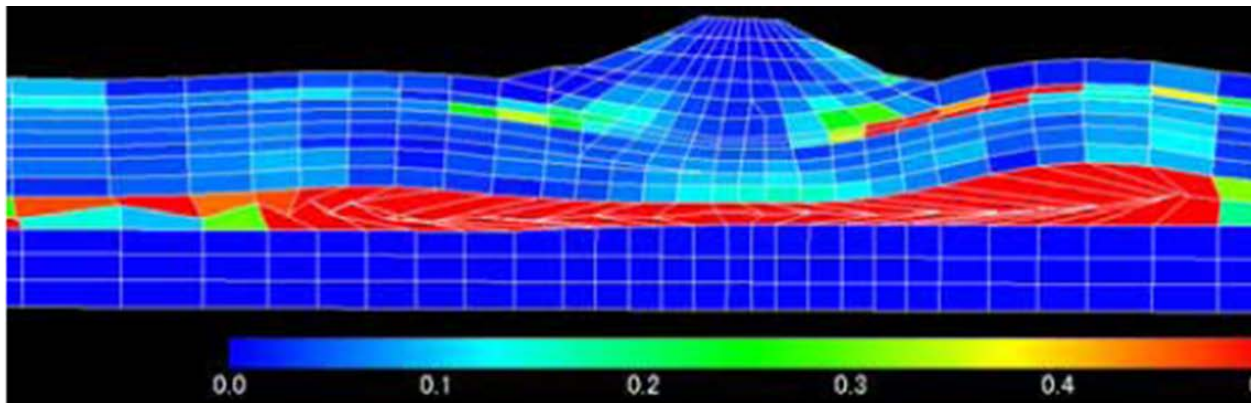


settlements at crest (cm)

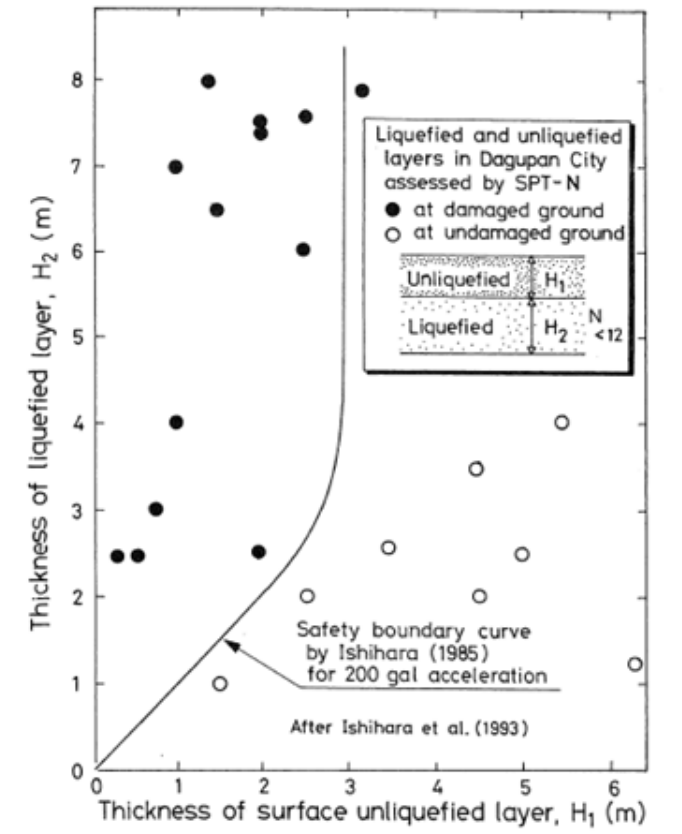


Case designation for numerical analysis

Case No.	S_{us} (kPa) for $A_{sa}-A_{ca}$	S_{us} (kPa) for A_{s1}	S_{us} (kPa) for A_{s2}
A	∞	∞	∞
B	0.1	180	50
C1	25	180	50
C2	50	180	50
C3	75	180	50
C4	100	180	50
D1	0.1	100	25
D2	0.1	25	7
D3	0.1	15	5

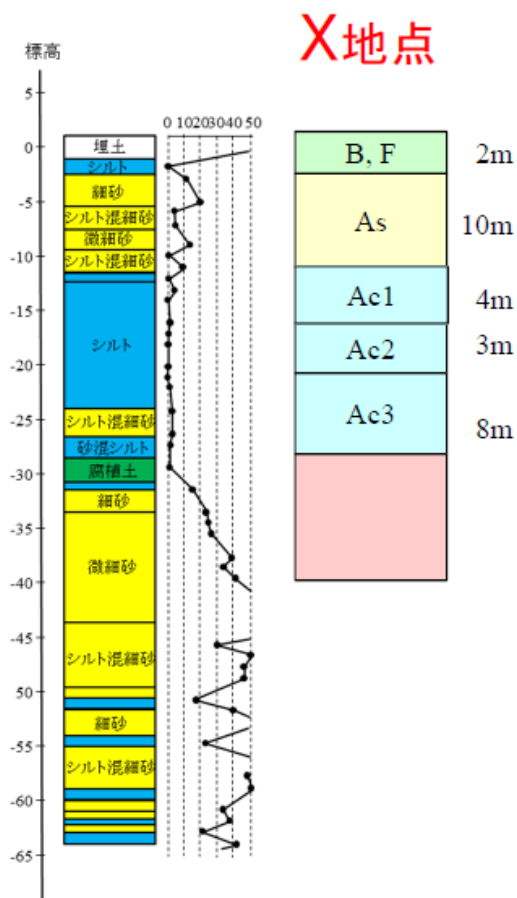


Effect of water migration: Delayed deformation/failure



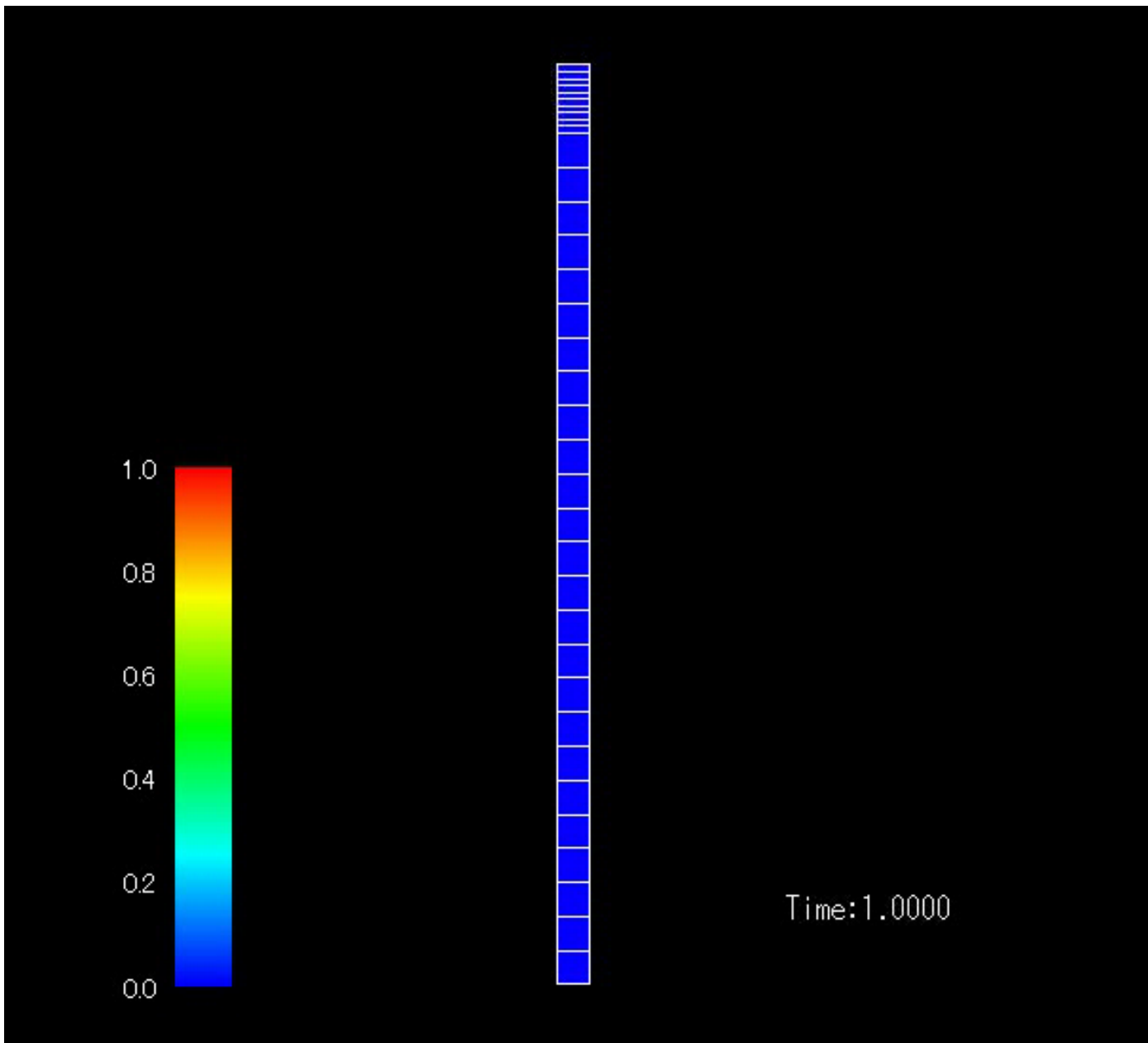
Ishihara et al (1993)

Surface crust (capping clay layer)



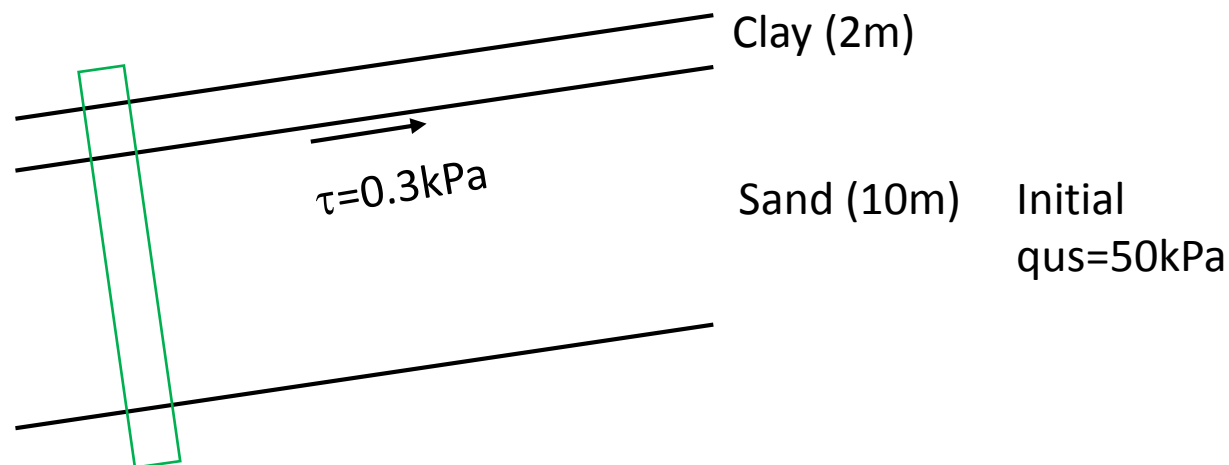
サンプリング地点

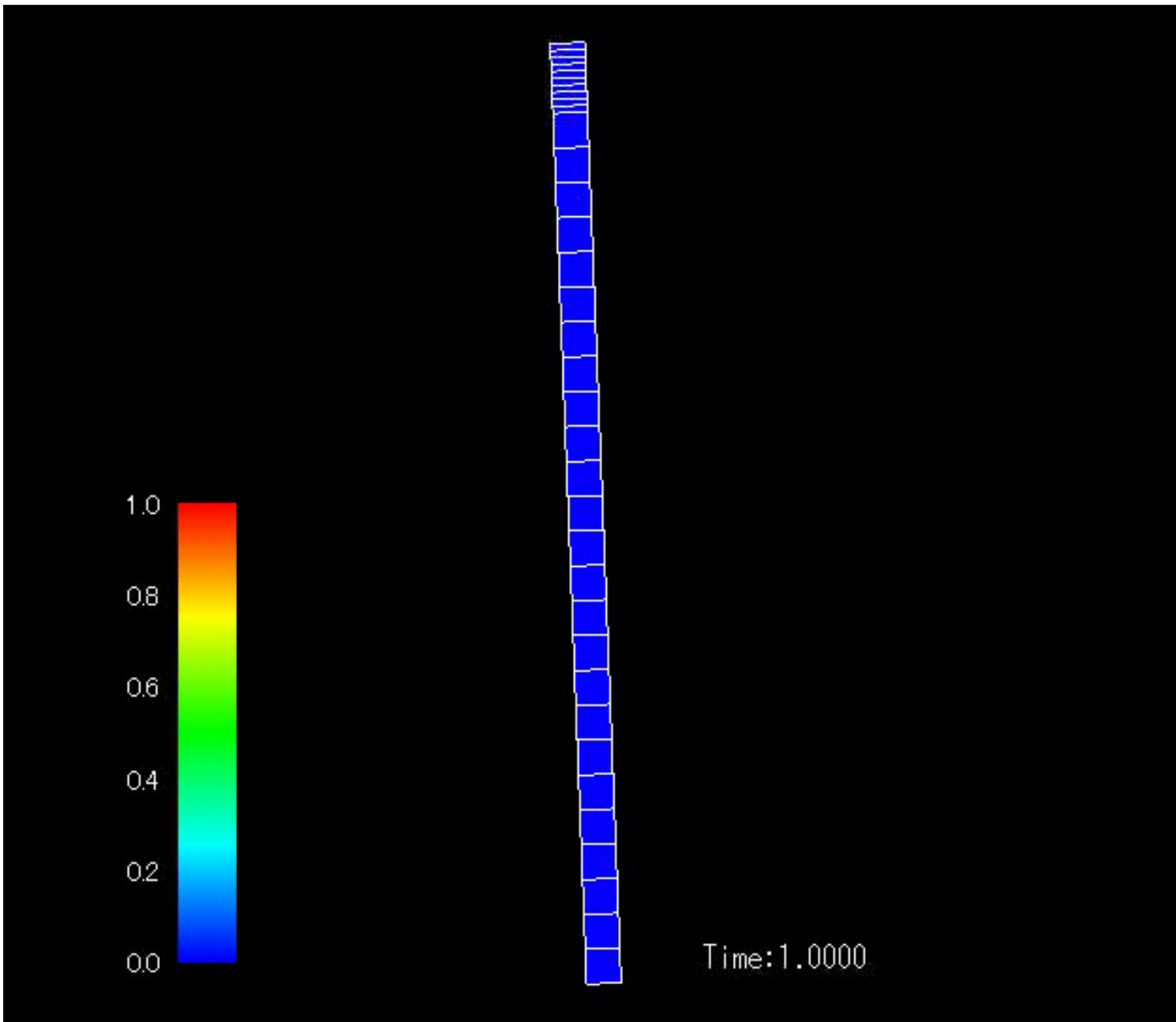




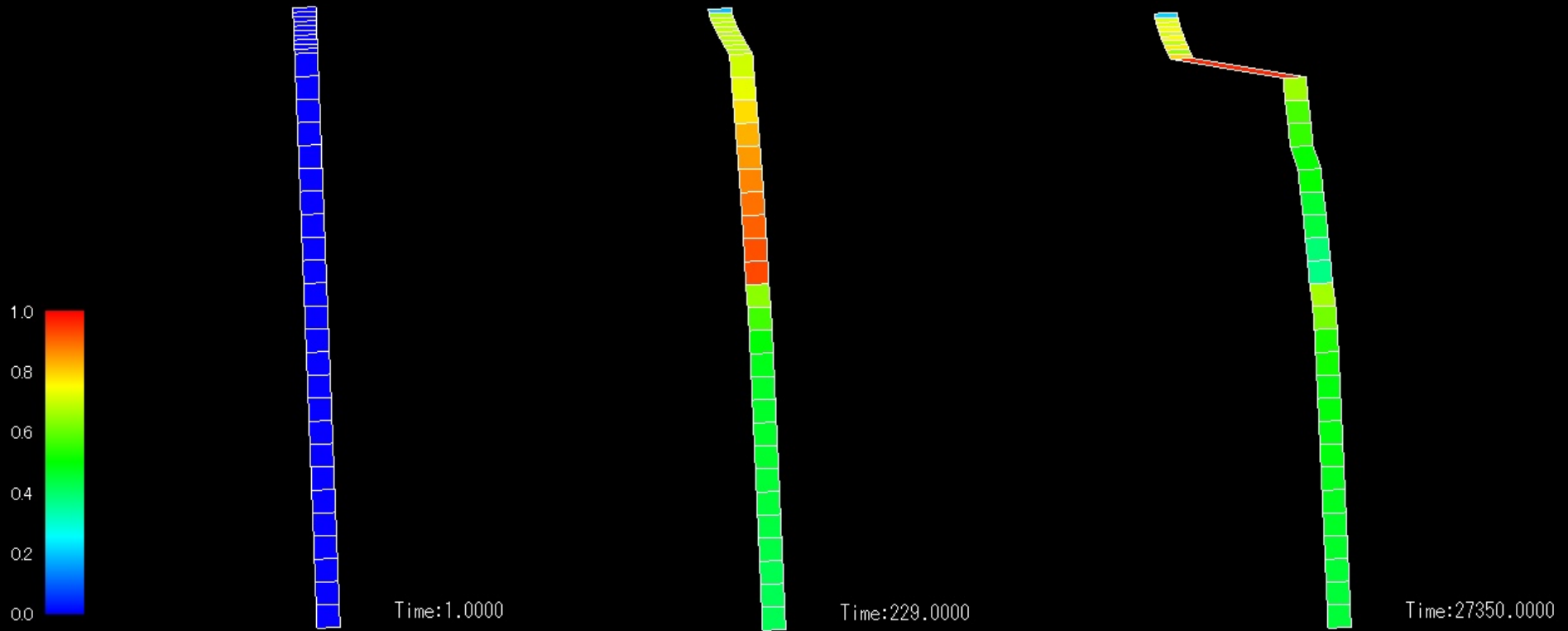
Surface crust (mild sloping ground with capping clay layer)

- Mild sloping ground: 2 degrees
- Initial undrained residual strength of sand layer $q_{us}=50\text{kPa}$
- Static shear stress due to the capping clay layer with mild slope: $\tau=0.3\text{kPa}$



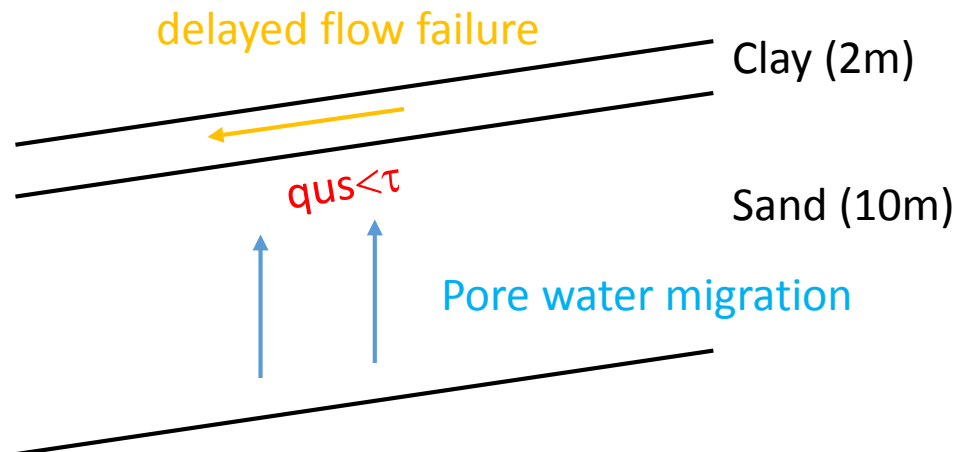


Delayed flow failure (analysis)



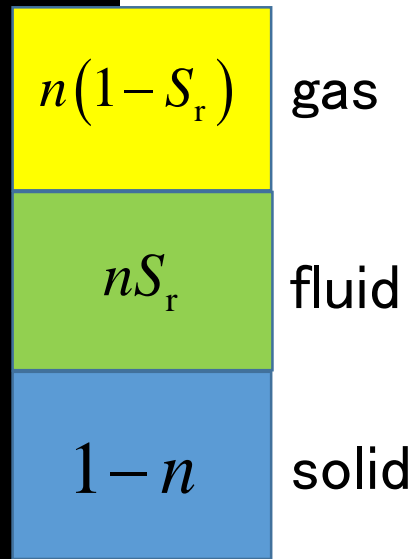
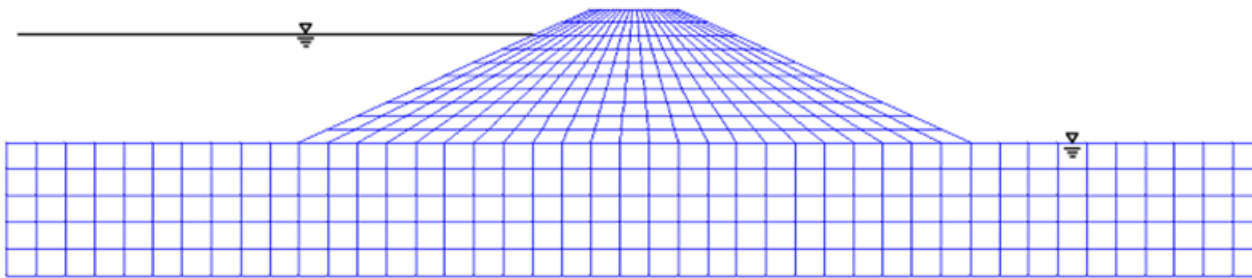
Mechanism in delayed flow failure

- Pore water migration into the sand just below the capping clay layer \Rightarrow volume expansion of the sand \Rightarrow reduction in q_{us}
- When $q_{us} < \tau$, delayed flow failure is triggered.

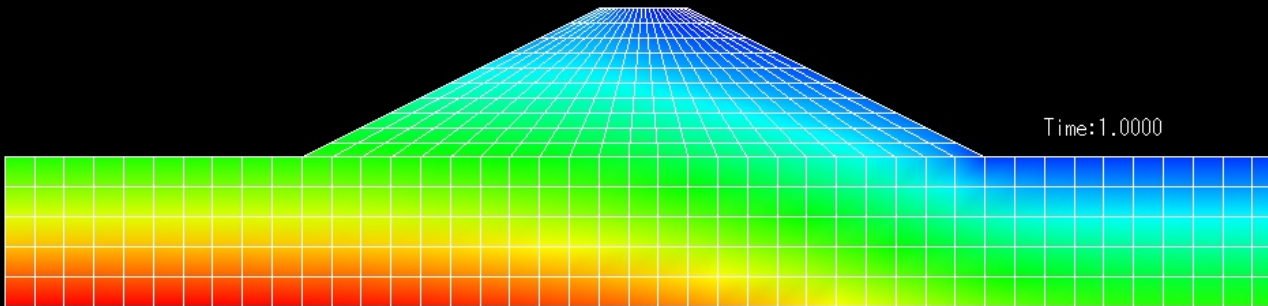


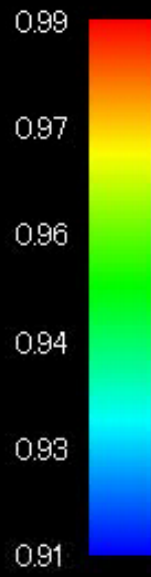
Effects of partial saturation: three phase medium

スケール 0 5 (m)



Time: 1.0000





Time:0.2000

Summary: paths forward

- Undrained monotonic shear
 - Uncertainty in differentiation of steady state from quasi-steady state in practice.
- Effect of initial shear (stress induced anisotropy)
 - Well established in theory and modelling. Slow in use in practice.
- Combination of cyclic shear and steady state
 - Need more case histories for verification.
- Effect of water migration: delayed deformation/failure
 - Possible to numerically simulate, provided that numerical scheme is robust and reasonably accurate.
- Effect of partial saturation
 - Challenge: High compressibility of air, effect of suction.