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Stress-induced anisotropy of small strain shear modulus in saturated and unsaturated cohesive soils

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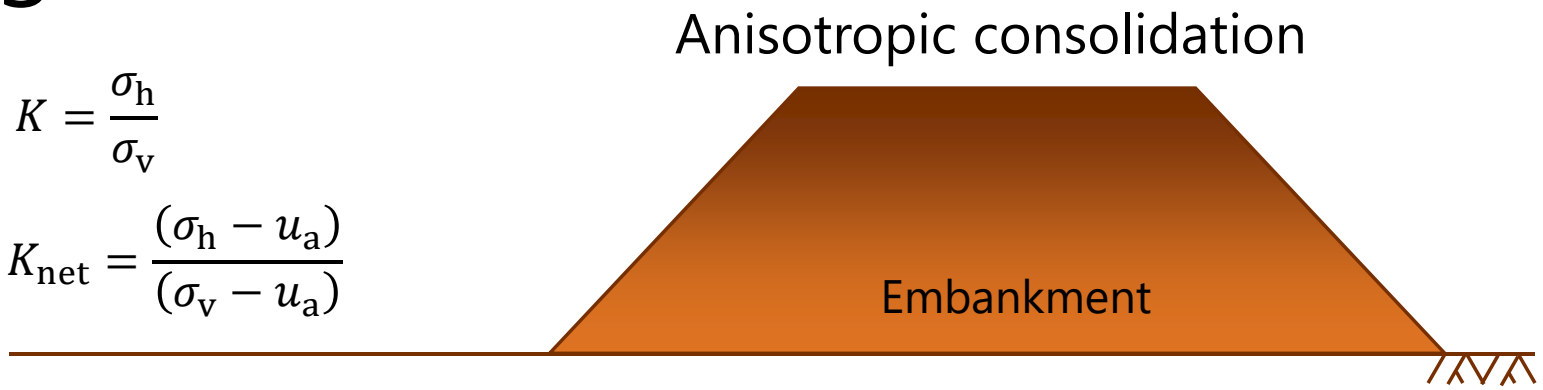
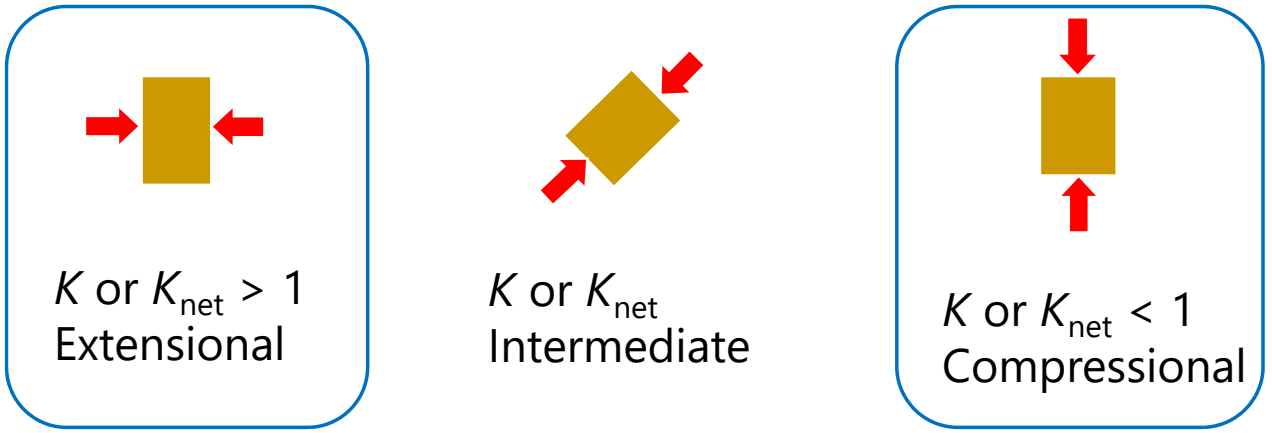
Background

Saturated: $K = \frac{\sigma_h}{\sigma_v}$

Unsaturated: $K_{net} = \frac{(\sigma_h - u_a)}{(\sigma_v - u_a)}$





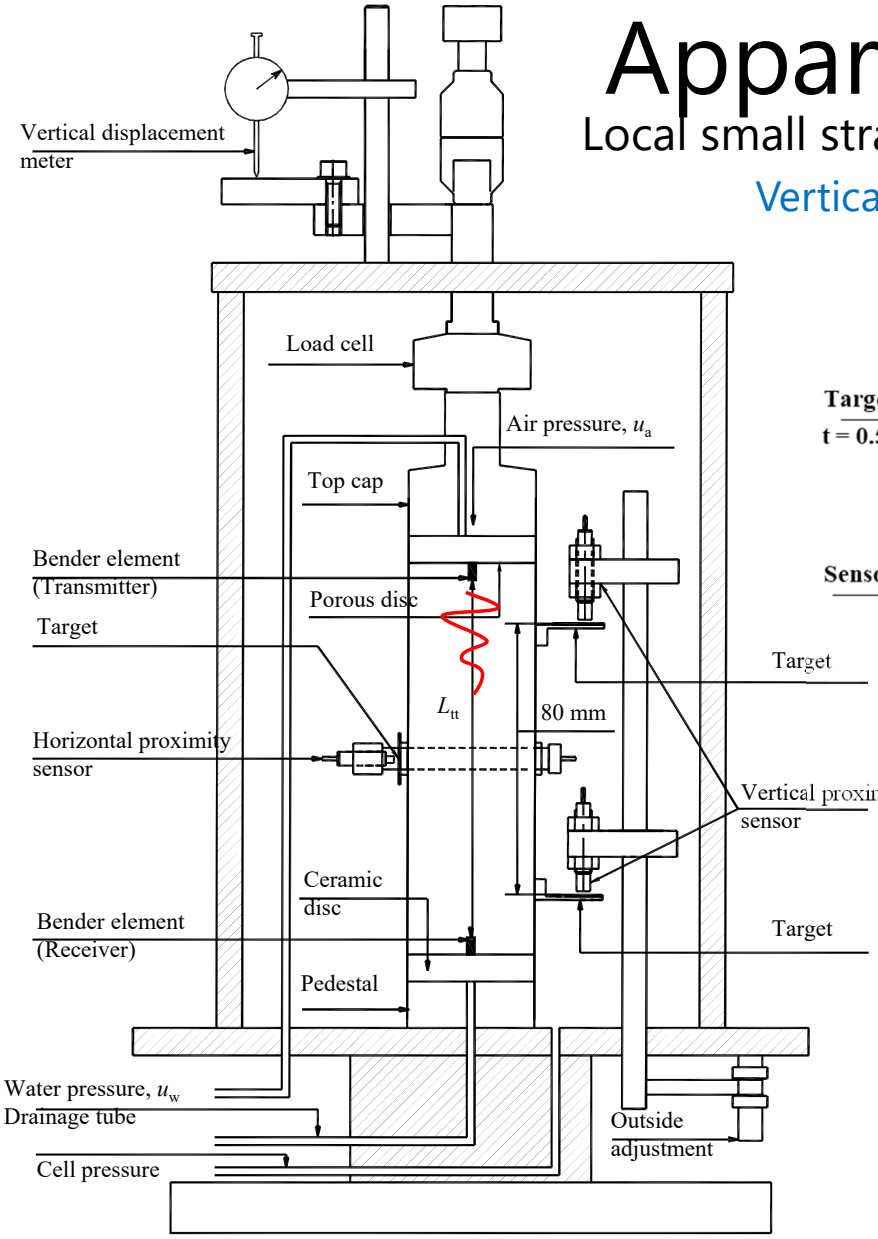
Out of scope
Intermediate: shear stress or inclined loading

Objectives

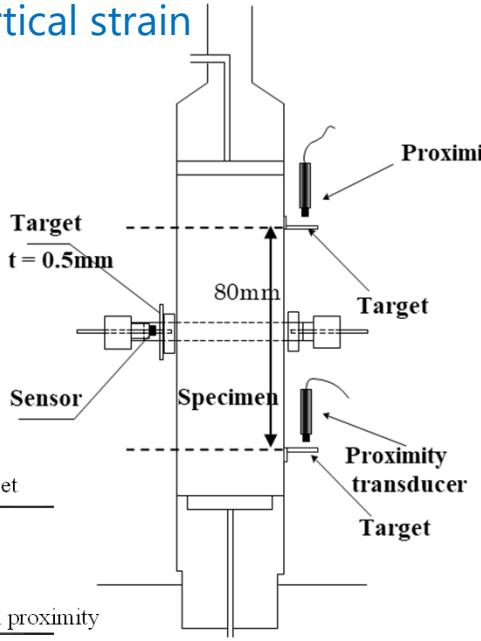
- To create different K or K_{net}-consolidated specimens (Anisotropic consolidation)
- To measure G_0 and G_{sec} (Stress-induced anisotropy)
- Normalize G_0 to remove effects of K or K_{net} (for prediction)

Apparatus used

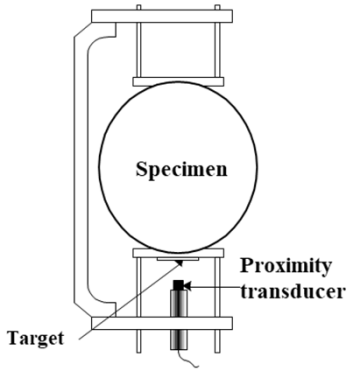
Local small strain (LSS) measurement

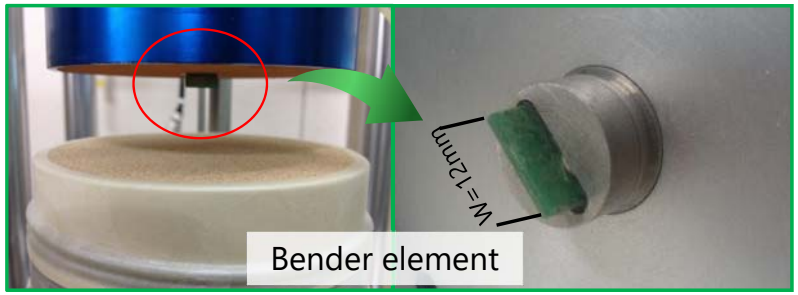


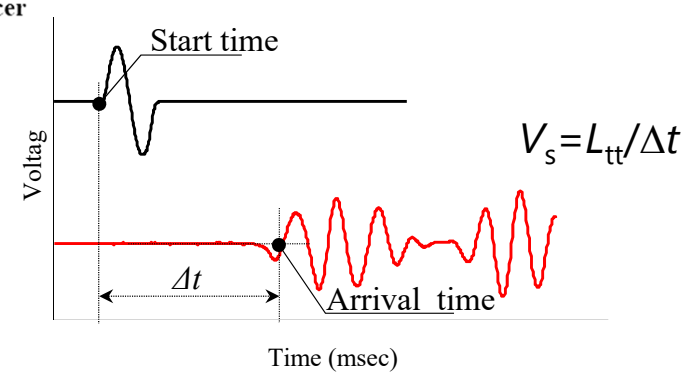
Vertical strain



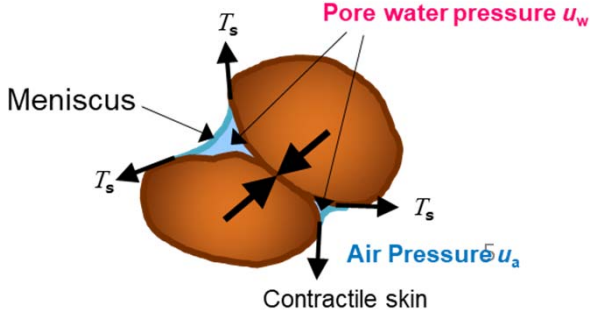
Horizontal strain







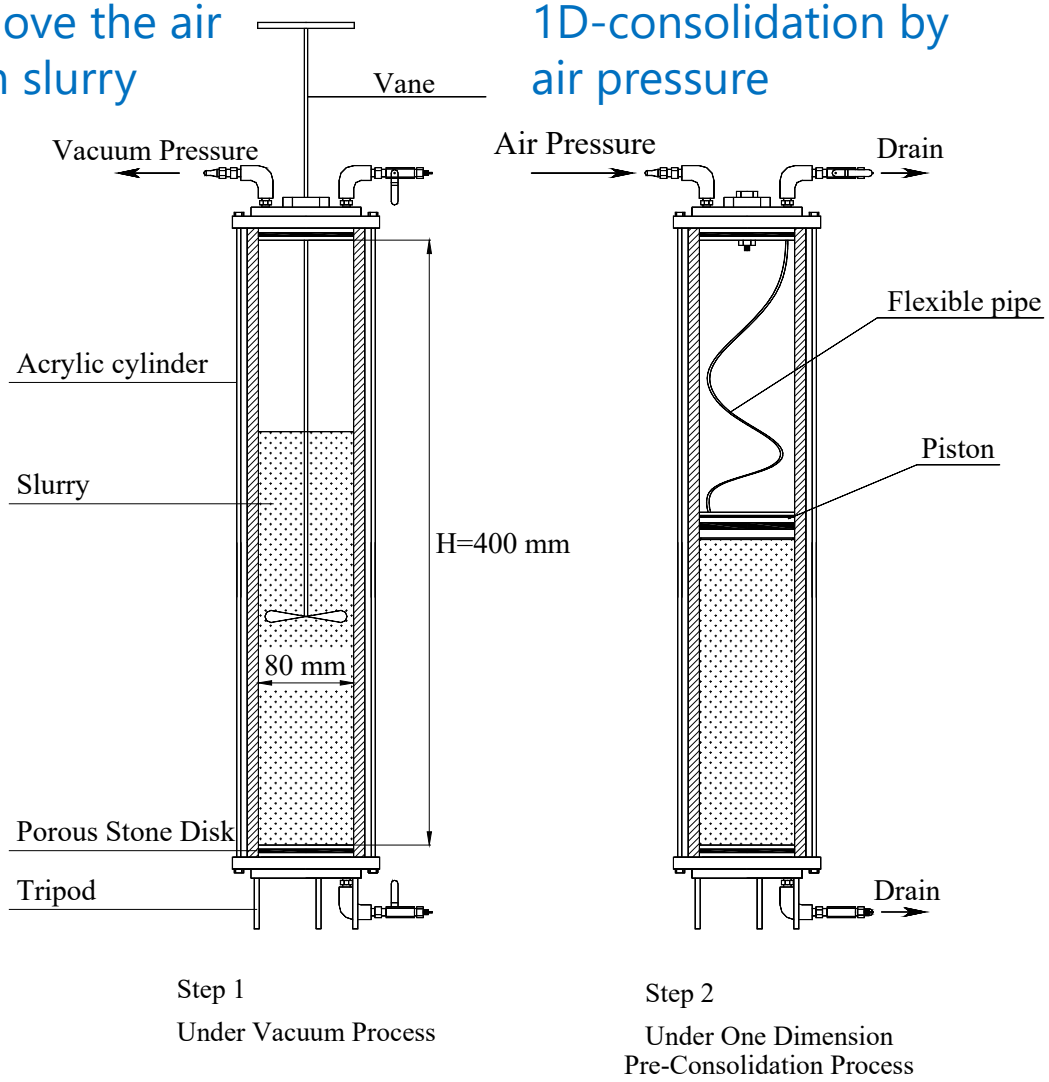
Unsaturated soils: Pressure plate method



Specimen preparation

Remove the air from slurry

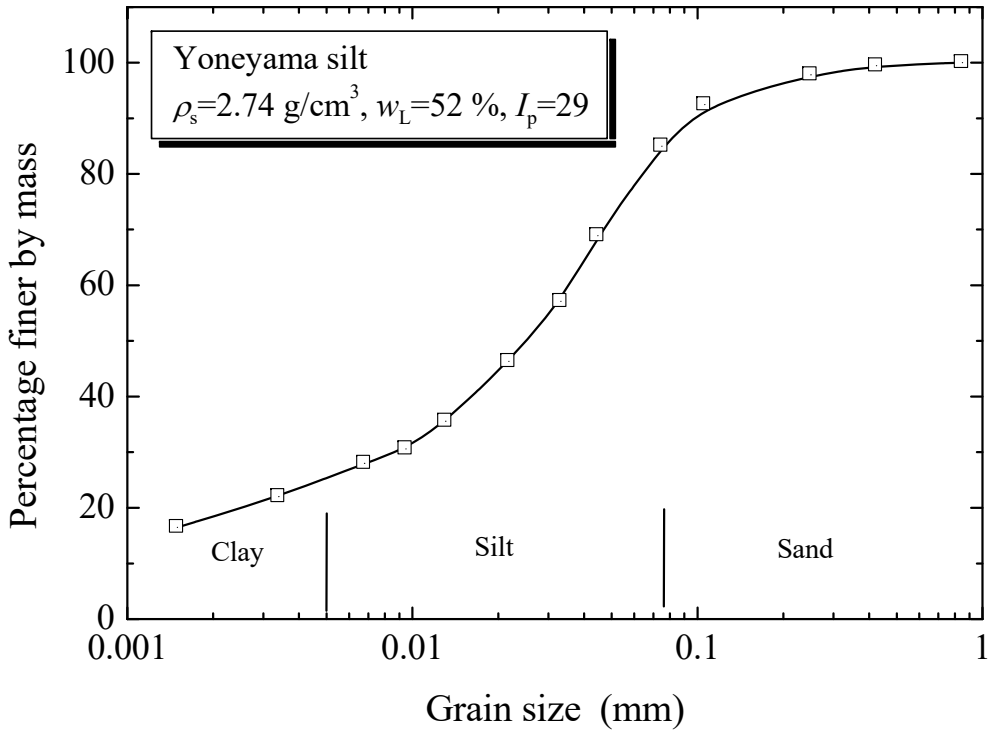
1D-consolidation by air pressure

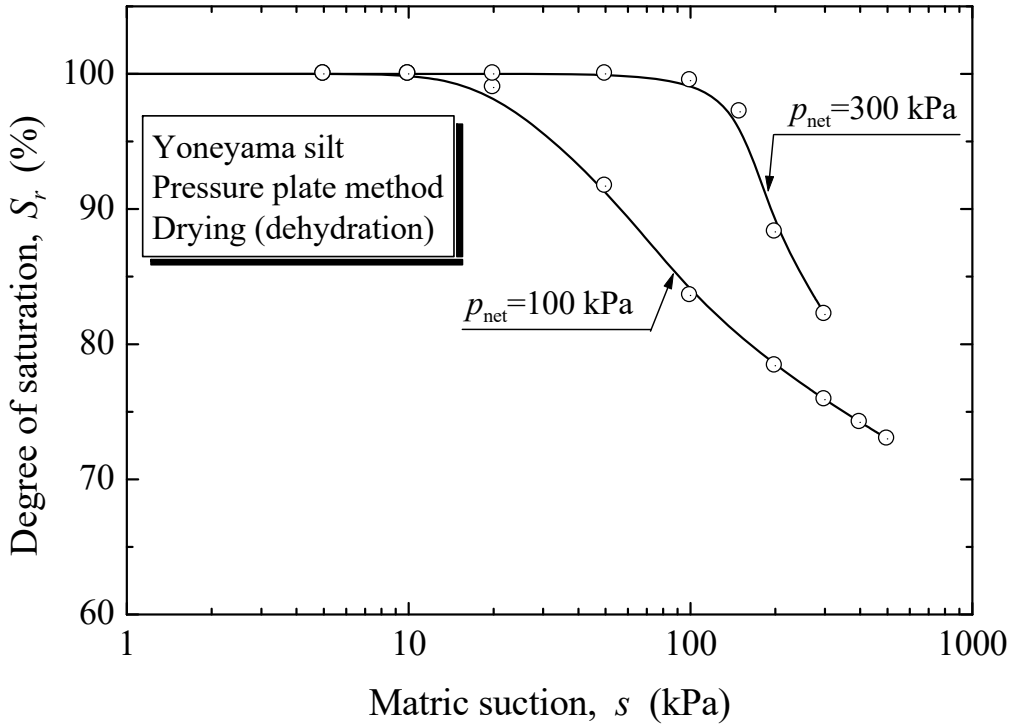


Extracted soil block

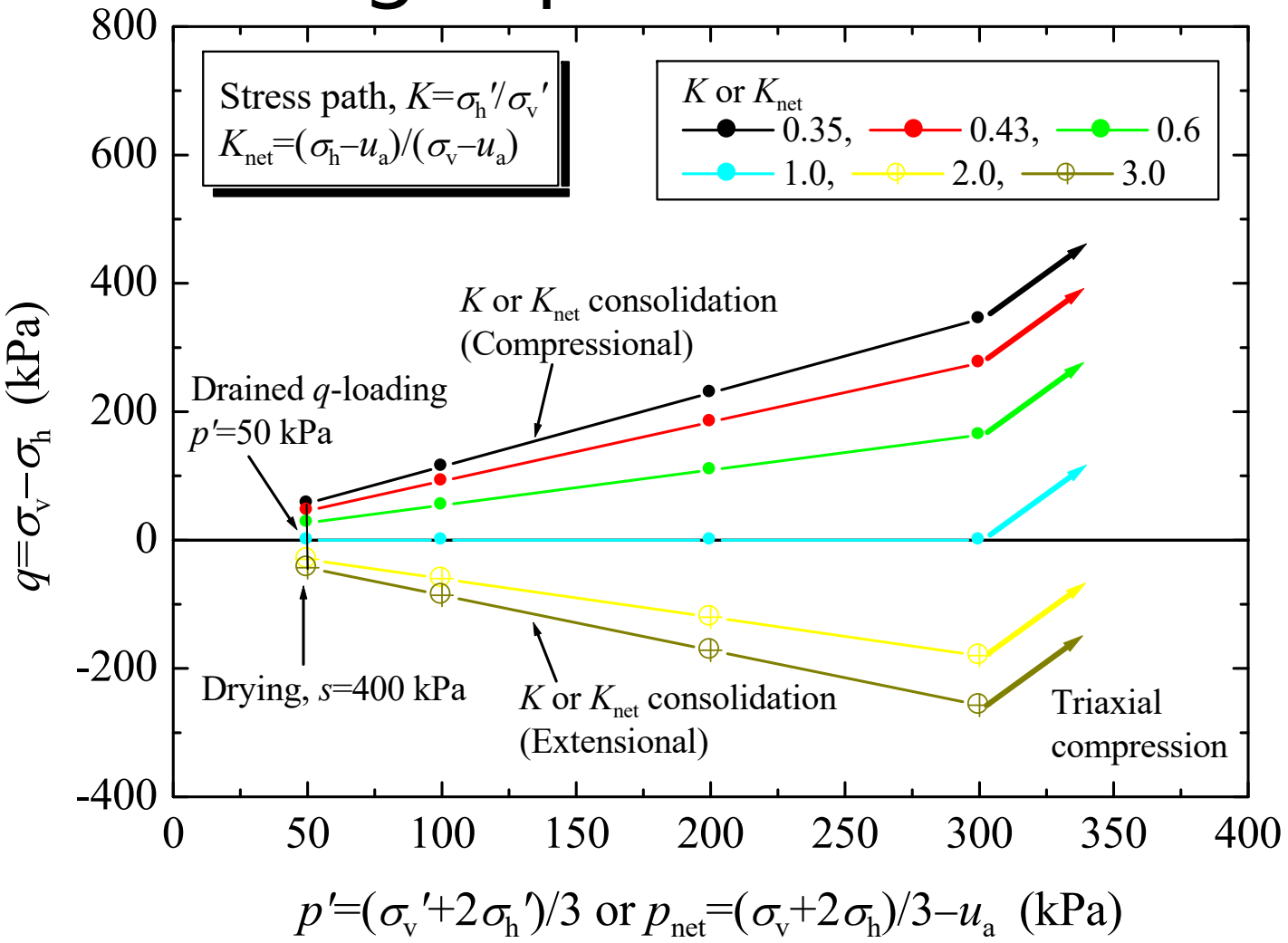
Trimmed
125 mm height
50 mm diameter

Material used



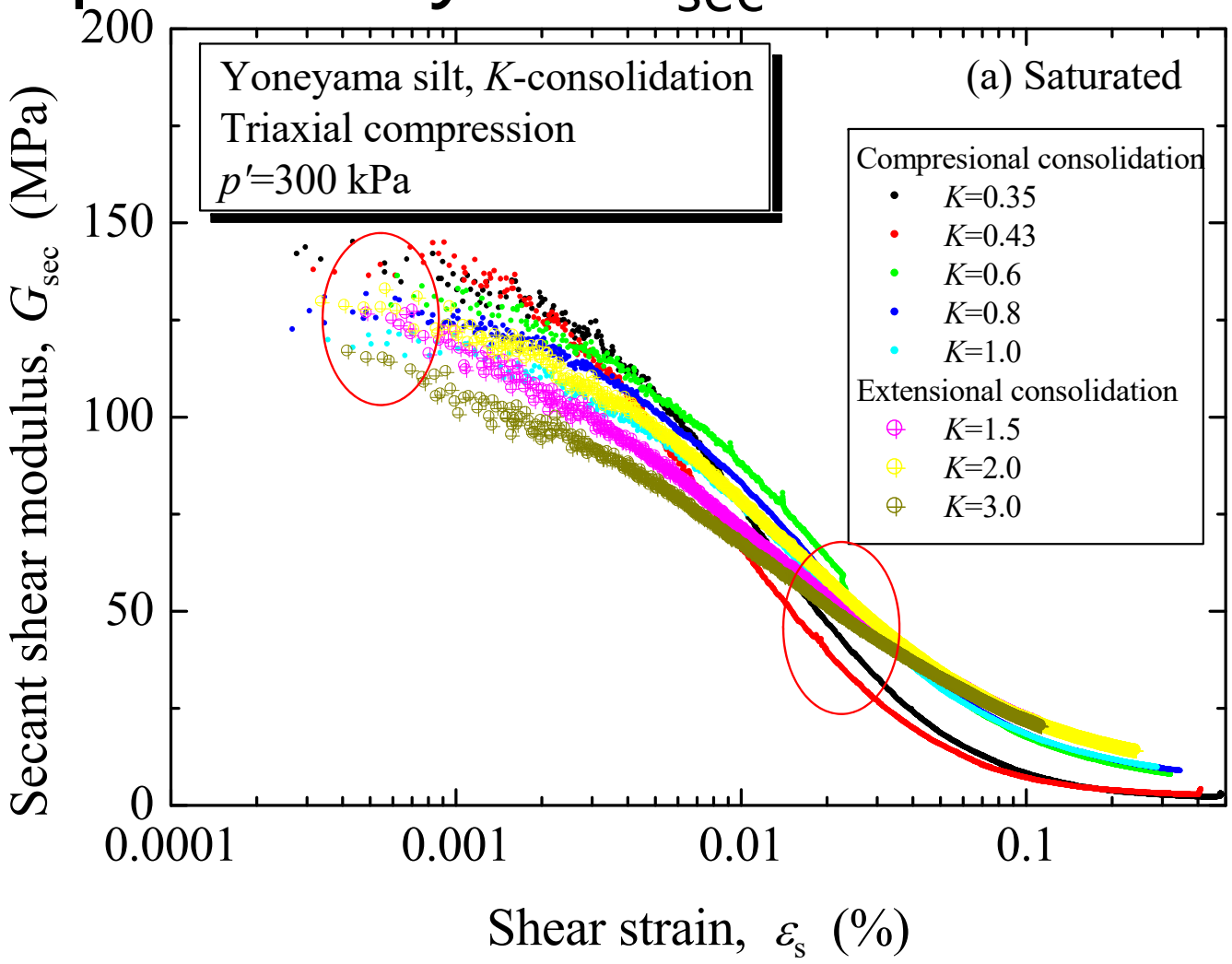


Stress path during experiment



Strain dependency of G_{sec}

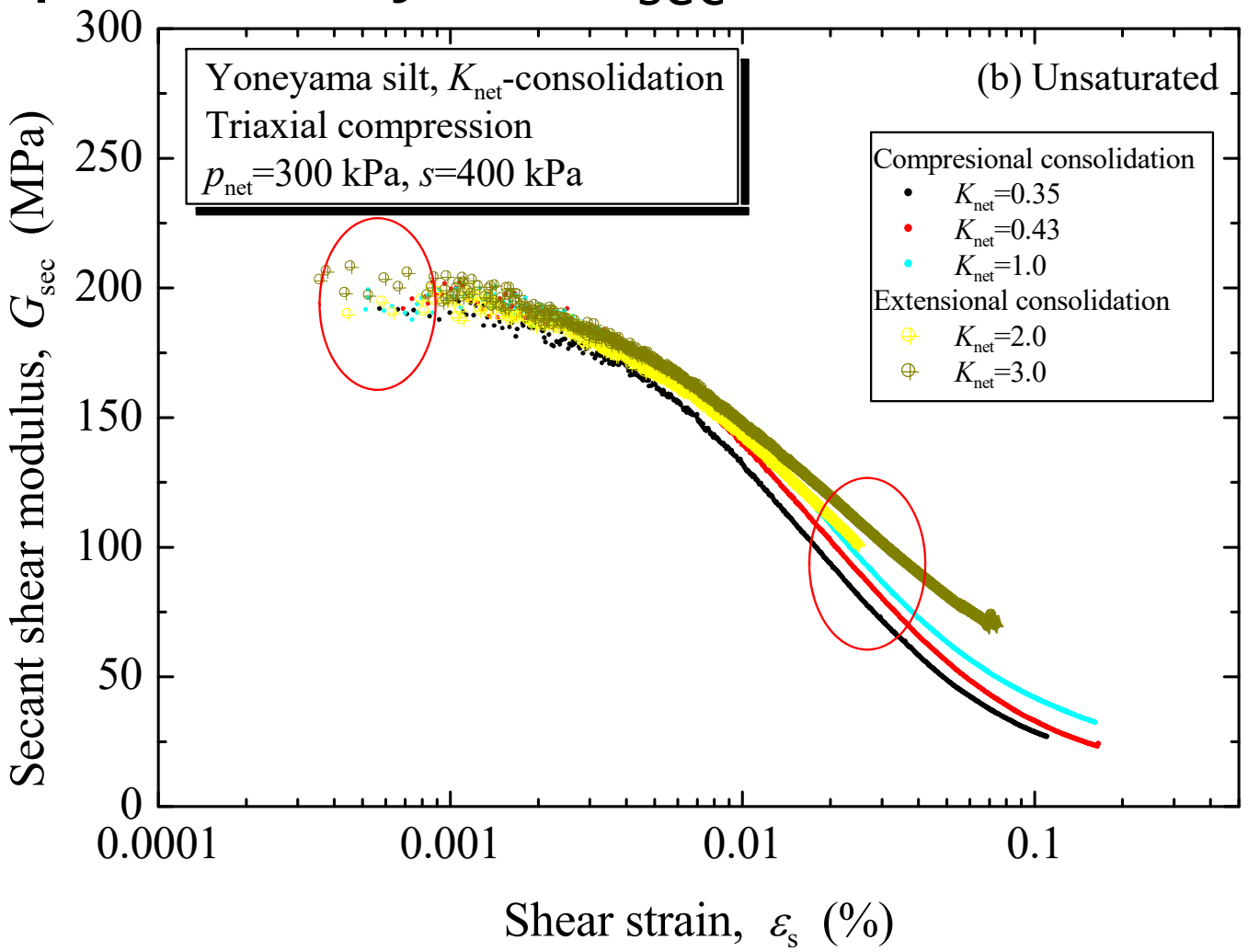
Saturated soil



$$G_{\mathrm{sec}} = \frac{\Delta q}{3\Delta \varepsilon_{\mathrm{s}}}$$

Strain dependency of G_{sec}

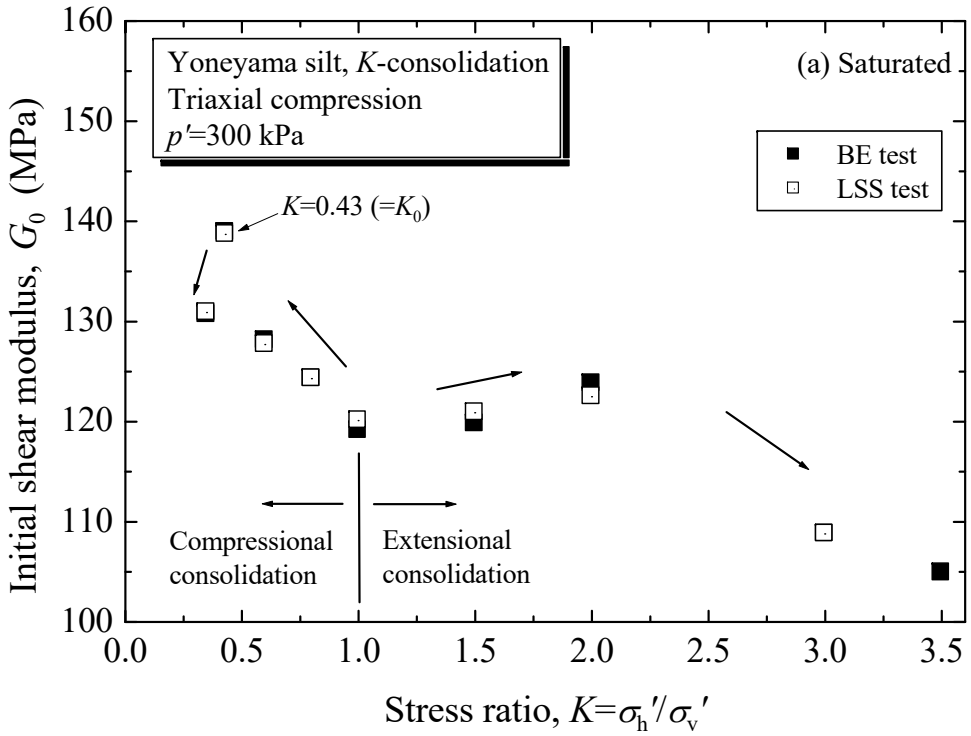
Unsaturated soil



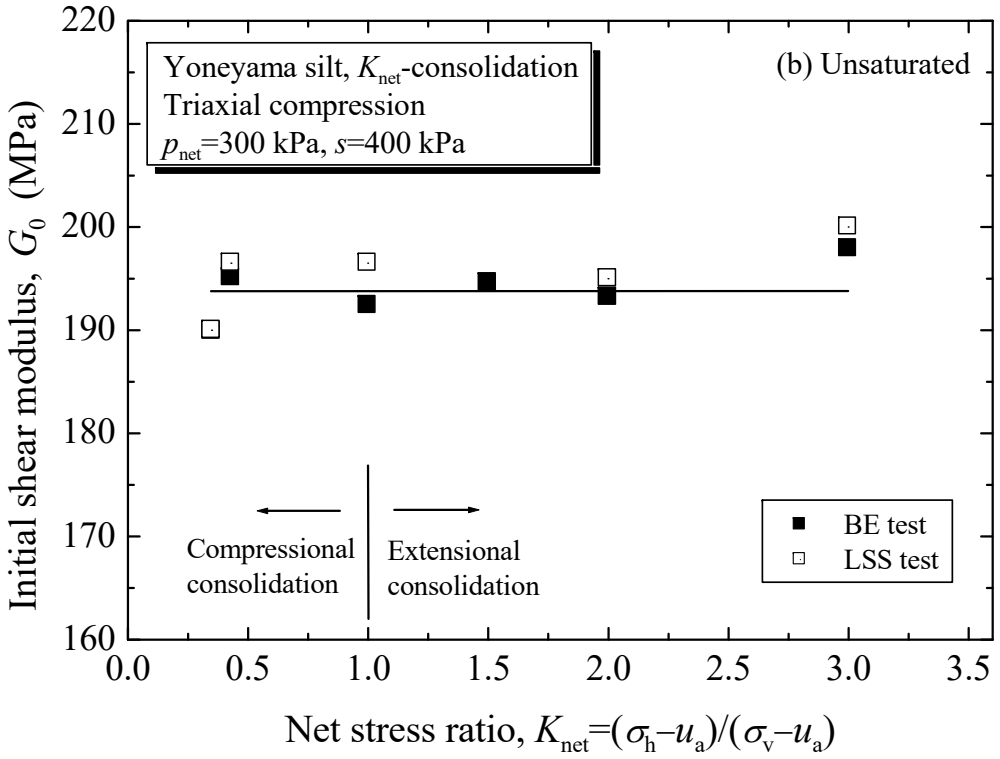
$$G_{\mathrm{sec}} = \frac{\Delta q}{3\Delta \varepsilon_{\mathrm{s}}}$$

Anisotropic G_0

LSS vs BE tests

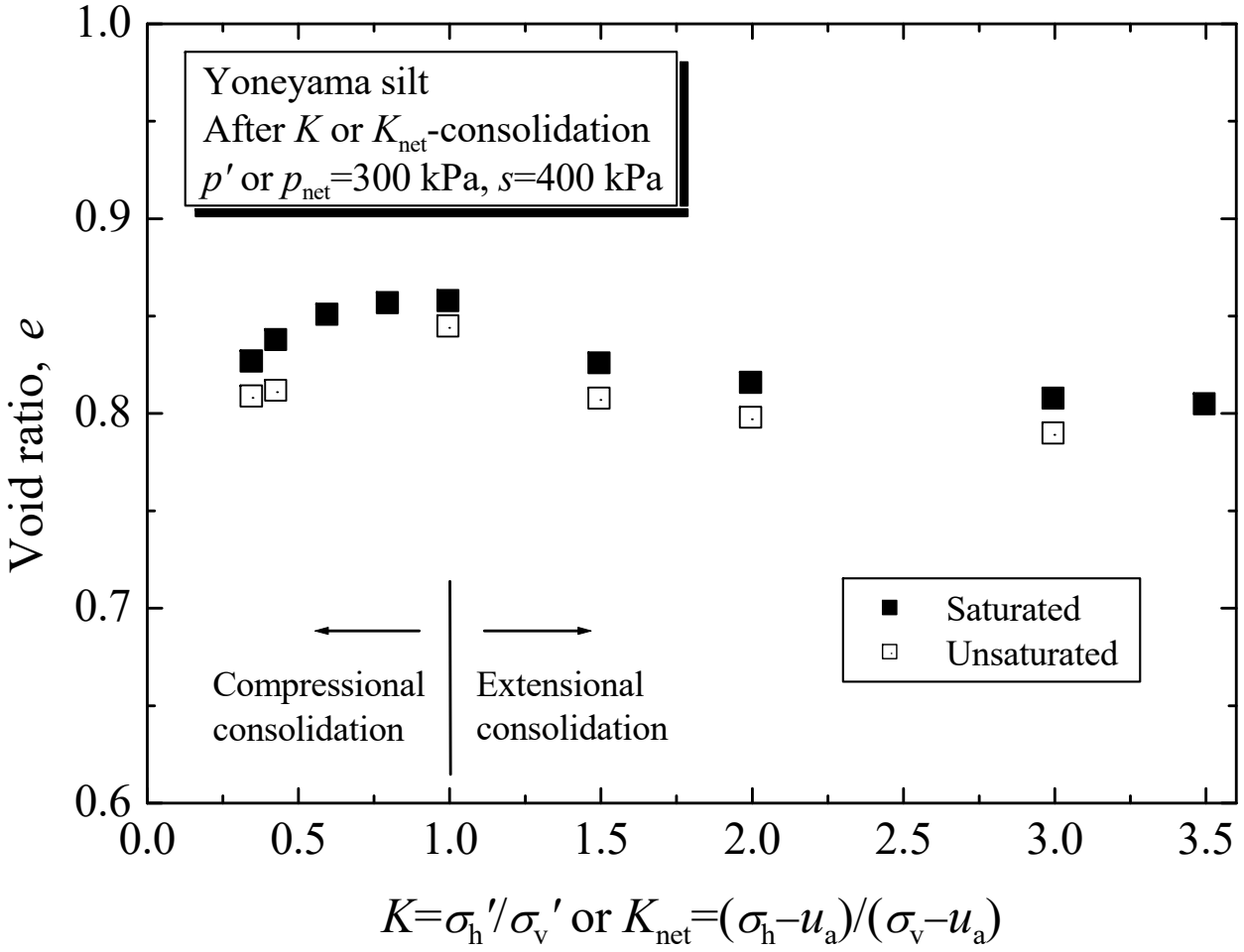


Saturated soil



Unsaturated soil

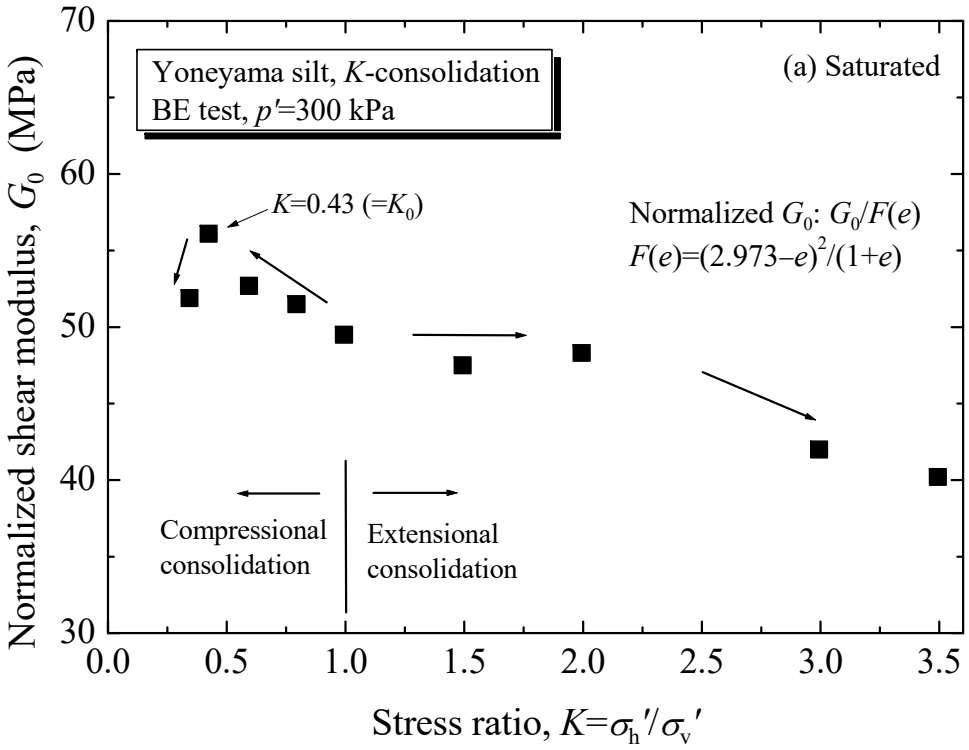
Void ratio function, $F(e)$



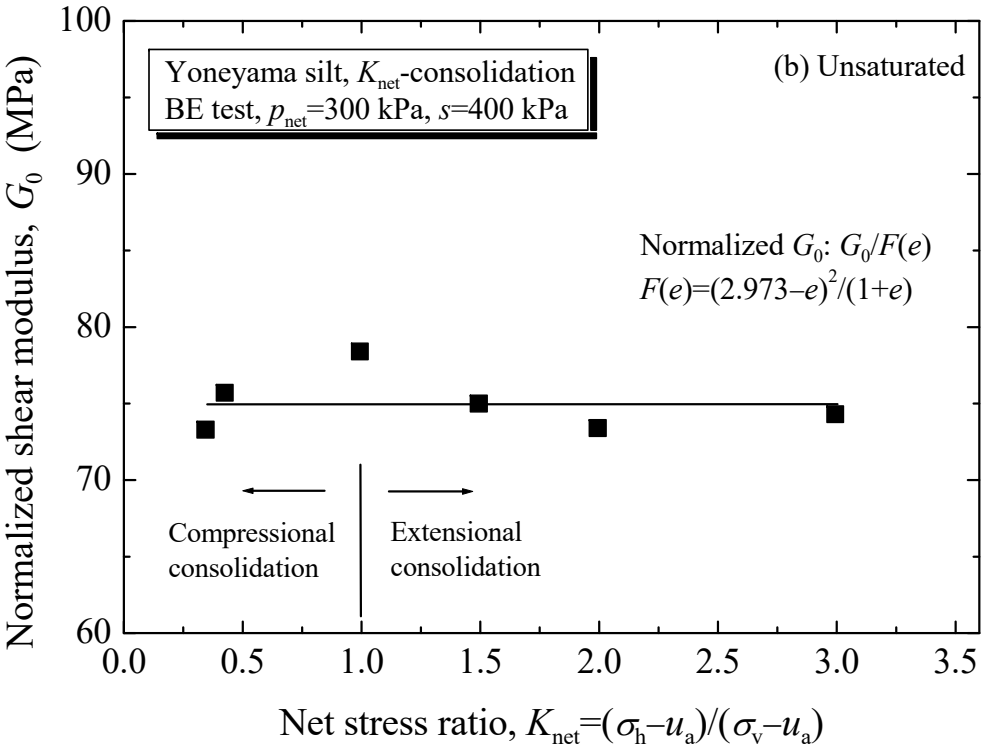
$$F(e)=\frac{(2.973-e)^2}{(1+e)}$$

Reported by
Hardin and Black (1968 and 1969)

Normalized G_0 by $F(e)$



Saturated soil



Unsaturated soil

Stress functions

Unsaturated soil

$$G_0 = AF(e)p_a\left(\frac{p'}{p_a}\right)^n$$

Reported by
Hardin and Richart (1963) and
Hardin and Drnevich (1972)

$$n = 0.5$$

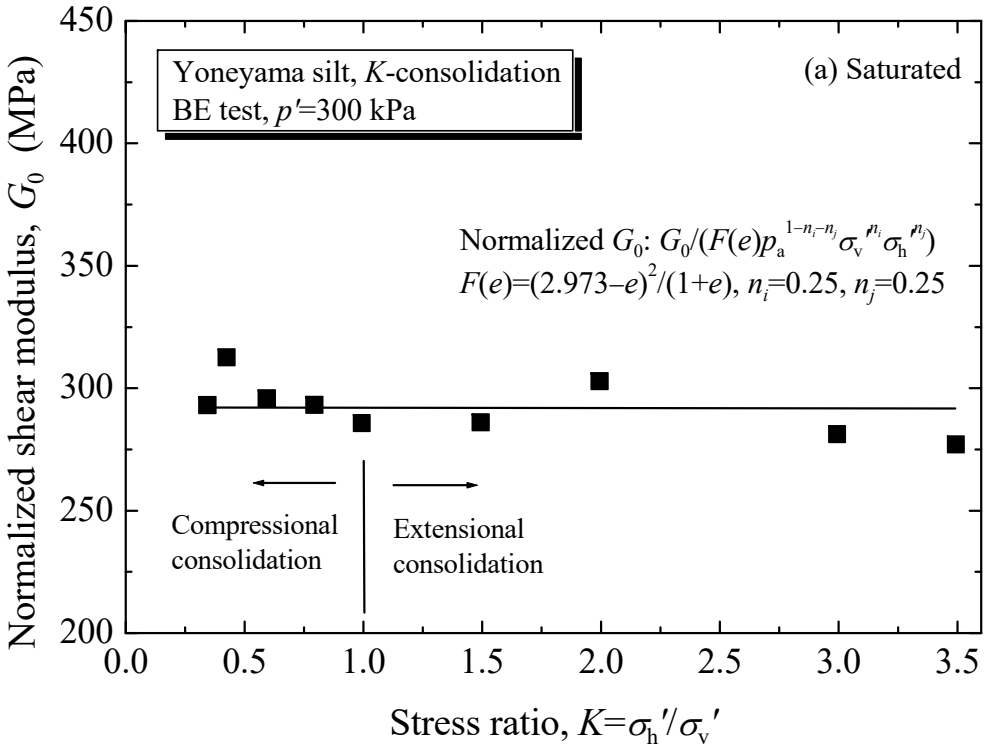
Saturated soil

$$G_0 = S_{ij}F(e)OCR^k p_a^{1-n_i-n_j}\sigma'^{n_i}_v\sigma'^{n_j}_h$$

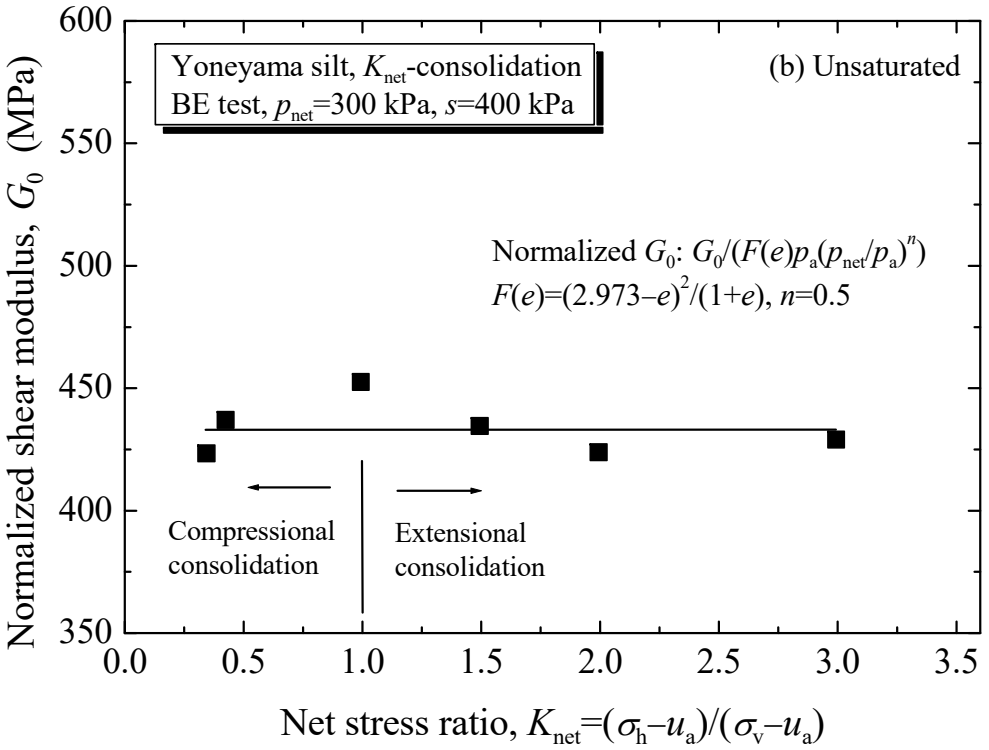
Reported by
Hardin and Blandford (1989) and
Jamiolkowski et al. (1995)

$$n_i = 0.25, \qquad n_j = 0.25$$

Normalized G_0 by $F(e)$ and stress function



Saturated soil



Unsaturated soil

Conclusions

- Very small shear strain: G_0 is strongly affected by anisotropic stress conditions in the saturated cohesive soil. However, those were not significant for the unsaturated cohesive soil.

- Shear strain greater than 0.03%: The trends of G_{sec} are changed from the trends of G_0. Degradation with shear strain is large in small K value.

- The values of G_0 under anisotropic stress conditions are normalized successfully using the void ratio function and the stress function.

Recommended normalized functions

$$F(e) = \frac{(2.973 - e)^2}{(1 + e)}$$

Unsaturated soil

$$G_0 = AF(e)p_{\mathrm{a}}\left(\frac{p_{\mathrm{net}}}{p_{\mathrm{a}}}\right)^{0.5}$$

Saturated soil

$$G_0 = S_{ij}F(e)p_{\mathrm{a}}^{0.5}\sigma'^{0.25}_{\mathrm{v}}\sigma'^{0.25}_{\mathrm{h}}$$

Thank you for your kind attention!