Shear Wave measurement for Real-time Monitoring of Soil Fabric Changes due to shear

せん断に伴う粒子配向変化の弾性波を用いたモニタリング

Granular materials often demonstrate macro-scale anisotropic behavior. Traditional methods of assessing small strain stiffness through elastic wave propagation, typically applied vertically in triaxial tests, fall short in capturing the particle orientation and anisotropic characteristics of soils under dynamic shear conditions. This study presents a novel approach by modifying a conventional triaxial apparatus to include planar piezoelectric transducers capable of measuring elastic wave propagation (P-waves and S-waves) in both vertical and horizontal directions. The apparatus was used to test three granular materials under monotonic compression with multi-direction P&S wave measurement.

砂などの粒状材料は、マクロスケールで異方性を示すことが多い。従来の弾性波伝播を用いた微小ひずみ剛性評価法は、三軸試験で垂直方向に適用されることが一般的である。本研究では、従来の三軸装置に平面型圧電トランスデューサーを追加し、垂直および水平方向の弾性波伝播（P波およびS波）を測定できるよう改良した。この装置を用いて、3種類の異なる粒状材料をせん断し、鉛直・水平方向のP波およびS波を調べた。

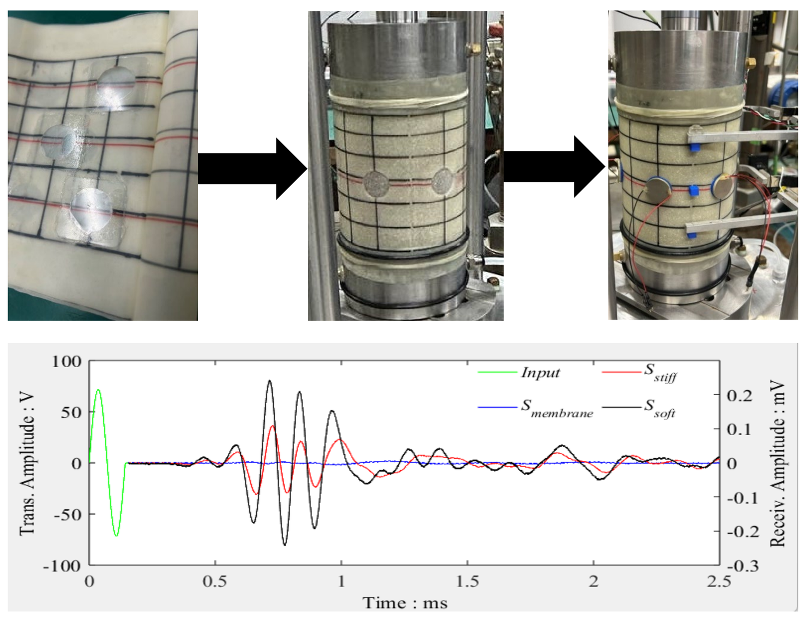
(1) Introduction

The design of safe and resilient structures necessitates thorough geotechnical investigation, where elastic wave velocity and small strain stiffness play crucial roles. Previous studies focused on vertically propagating waves using planar piezoelectric transducers, there is limited research on horizontally propagating waves research, which is not conducive to explaining the anisotropic characteristics of soil during dynamic shear processes. Therefore, the objective of this research is as follows:

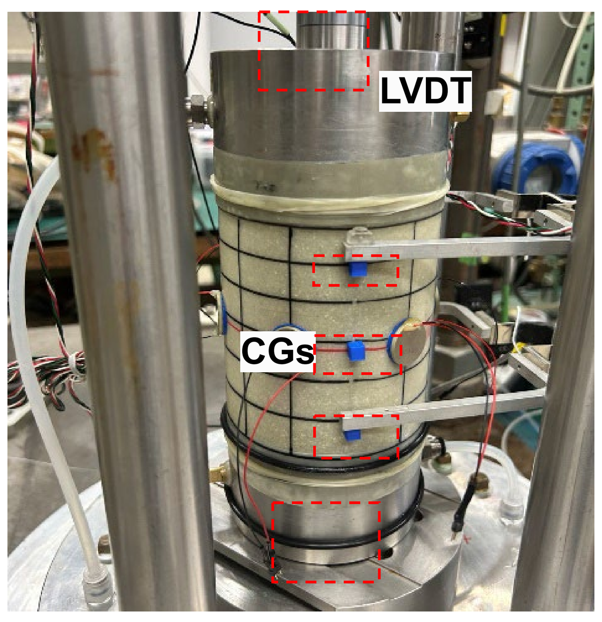
a) Evolution of stress wave velocity of two directions (vertical and horizontal) during triaxial compression
b) Influence of grain characteristics on the mechanical behavior of granular materials
c) Try to reflect the principle of particle orientation change and anisotropy from the relationship between vertical and horizontal waves in dynamic shear processes

(2) Experimental Procedure-Membrane Setup&Experimental Setup

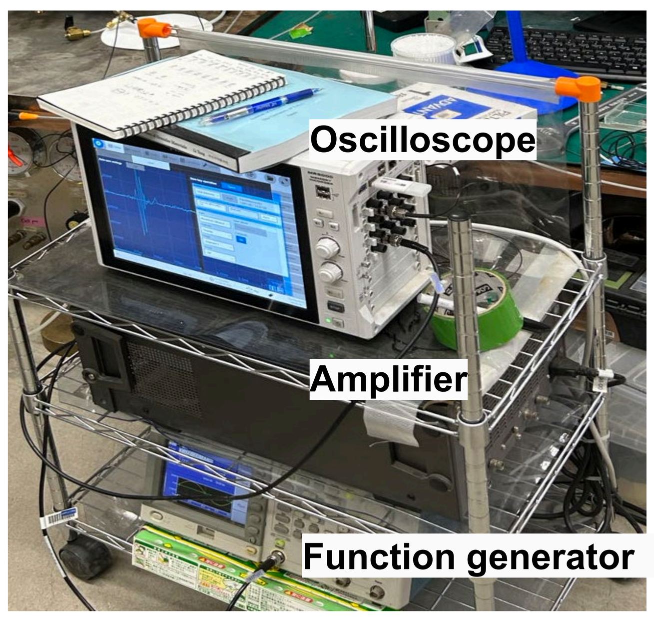
New methodology for testing horizontal wave



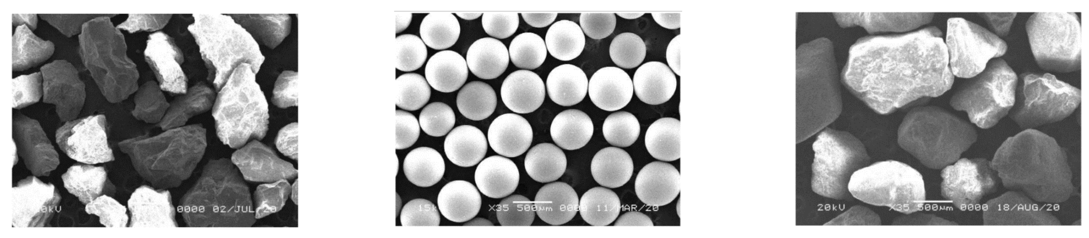
Sensor installation



Wave measurement

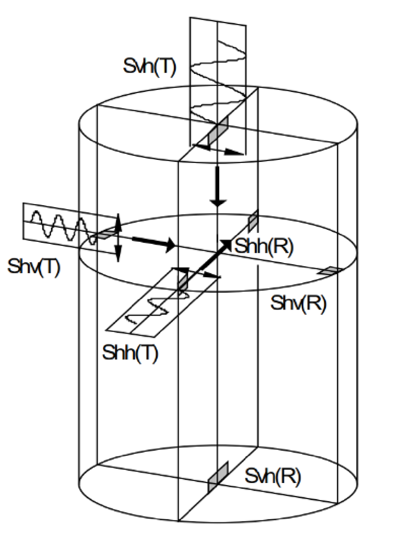


Testing materials

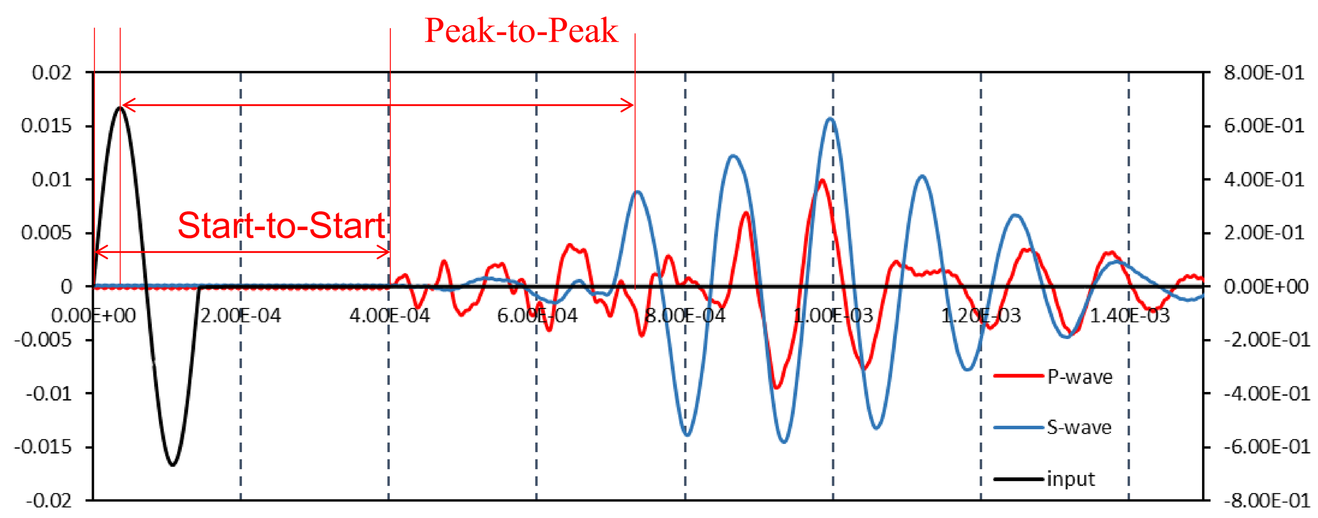


Materials	Silica Sand No.5 (SS5)	Smooth Spherical Glass Beads (SSGB)	Natural River Sand (NRVS)
G_s	2.64	2.5	2.66
e_{min}	0.699	0.589	0.622
e_{max}	1.067	0.694	0.882
D_r	14%,60%,80%	14%,60%,80%	14%,60%,80%

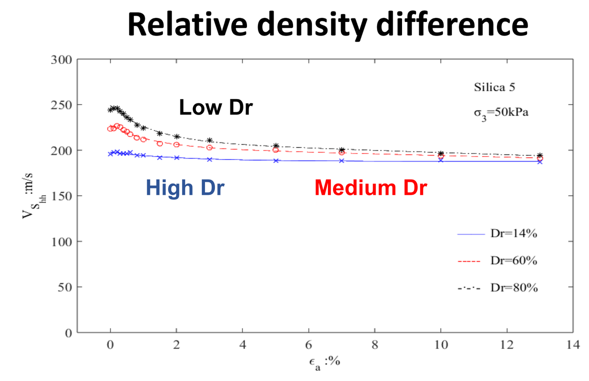
(3) Dynamic Wave Propagation Tests

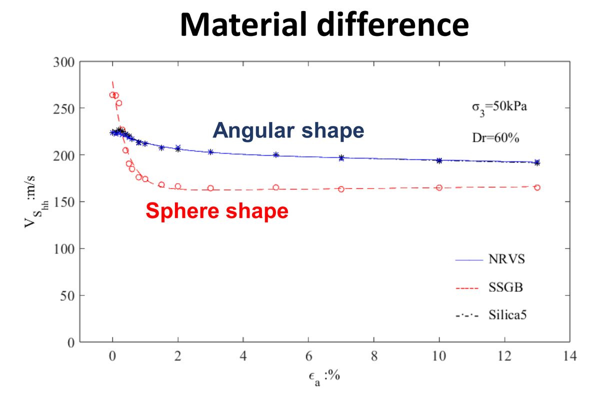


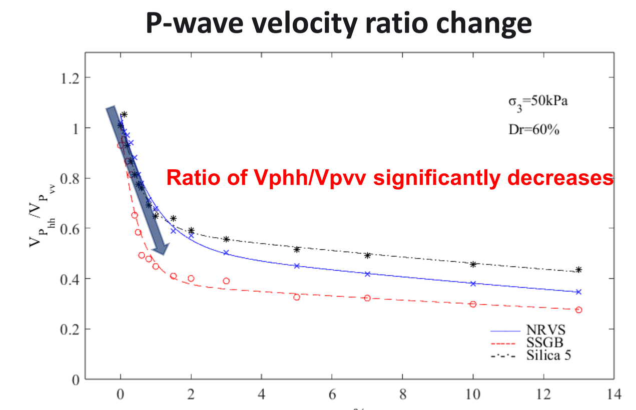
- ✓ Considering both P- and S-waves, there are six types of elastic wave components as illustrated the left hand.(e.g. Svh means Shearing Wave which spreads vertically but vibrates horizontally)
- ✓ When calculating the velocity of elastic waves, the time interval for P-waves is measured using the Start-to-Start reading, while the time interval for S-waves is measured using the Peak-to-Peak reading (P-waves travel faster, thus using the Start-to-Start reading for S-waves would be affected by the interference from P-waves).



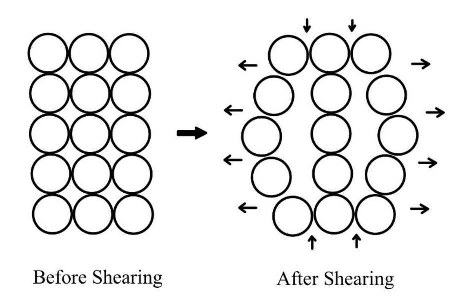
(4) Experimental Results

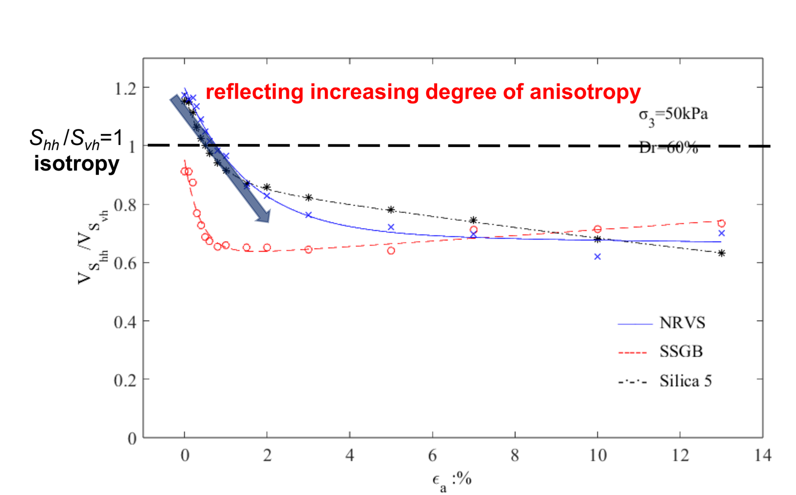






Reflecting dilatancy during shearing





Reflecting anisotropy during shearing

(5) Conclusion

- ✓ The relative density of granular samples significantly affects the small-strain stiffness at the initial stage of shearing, while different materials exhibit various elastic wave development trends due to changes in particle orientation during the shearing process.
- ✓ The decrease in the ratio of horizontal P-waves to vertical P-waves during shearing reflects the dilative characteristics of granular materials, with particle shape and orientation changes influencing this shearing behavior.
- ✓ The variations in horizontal S-waves and vertical S-waves indicate anisotropy in small-strain stiffness during dynamic shearing, with vertical stiffness typically being greater than horizontal stiffness.

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