Anisotropy of Shear Wave Velocity
- Role Of Grain Shape -
せん断波速度の異方性 - 粒子形状の影響

The mechanical properties of granular soils such as soil stiffness or strength depend on the direction of measurement. Until now, fundamentals of stiffness anisotropy have not been fully understood. In this study, four types of granular materials: spherical glass bead, Toyoura sand, Indica rice and wild rice are used to figure out particle shape effects on anisotropy of shear wave velocities. Besides, this study developed a cubical box equipped with multi-directional shear plates by which both P- and S-waves can be generated and received to understand the effect of particle shape on the anisotropy of multi-directional shear wave velocities.

地盤材料のような粒状体は力学的に異方性を示す。特に、地盤剛性や最大強度に関しては長年にわたって議論されてきた。しかし、いまだ経験的な解釈に留まっているのが現状である。本研究では、地盤剛性の異方性に対する粒子形状の影響を明らかにするために、4種類の粒状体（ガラスビーズ、豊浦砂、インディカ米、ワイルド米）を用いて弾性波（P波、S波）の計測を行った。地盤剛性の固有異方性を精度良く評価するために、3主軸方向にディスクトランスデューサーを搭載した立方体土槽を新たに製作した。

(1) Introduction : Anisotropy is the property of being directionally dependent, as opposed to isotropy, which means homogeneity in all directions. It can be defined as a difference in one soil mechanical property along different directions. Soil stiffness is one of the most important material properties that describe the relationship between stress and strain. Accurate measurement of multi-directional soil stiffness is still a challenge for experimentalists. However, recently, disk-transducer comprised of piezoelectric materials (referred to here as shear plate) has gained its popularity with several advantages over bender elements: soil specimen is not disturbed during sample preparation, coarse grains can be tested, more planar P- and S-waves can be generated.

(2) Materials

Four types of non-cohesive granular materials were used, they have narrow ranges of particle size distribution.

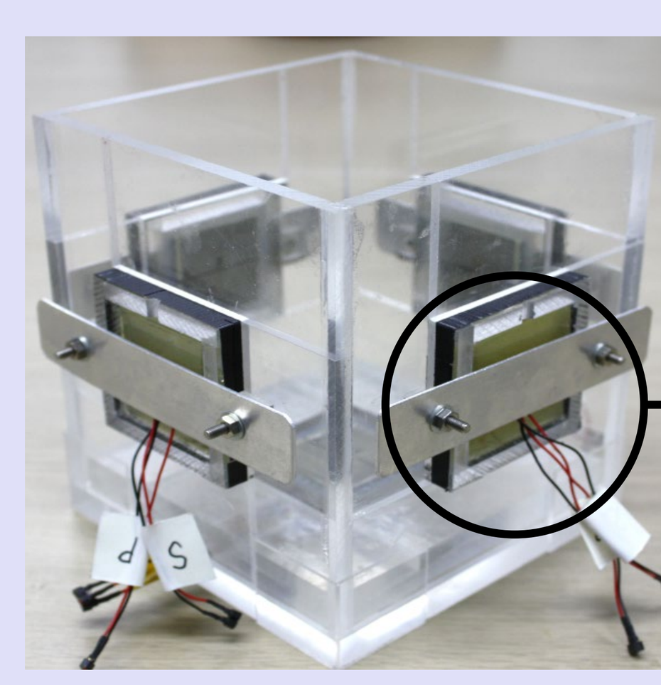
Glass Bead　Toyoura Sand　Indica Rice　Wild Rice

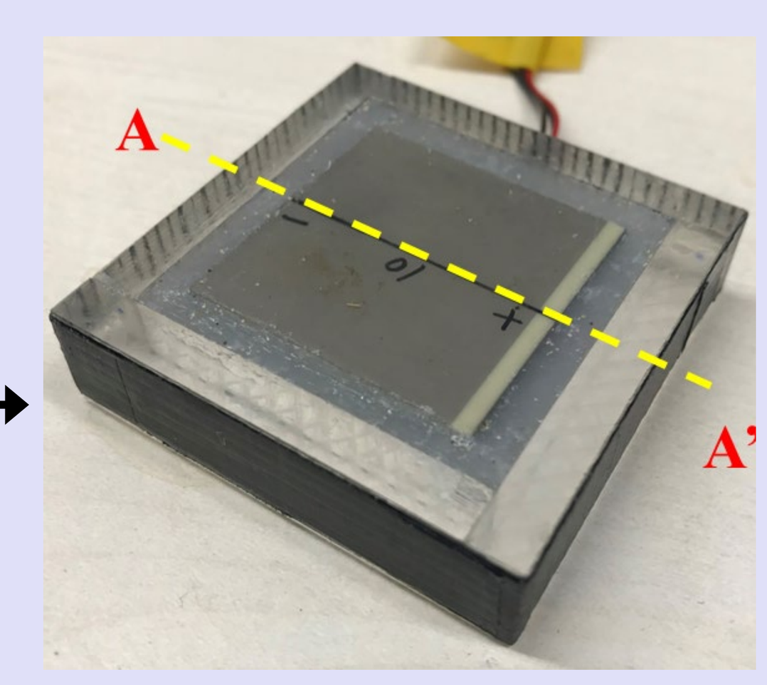
Material	Aspect Ratio	Dry Density g / cm³	$V_{S,HV}$ / $V_{S,VH}$	$V_{S,HH}$ / $V_{S,VH}$
GB	0.933	1.61	1.01	0.90
TS	0.592	1.63	1.04	1.13
IR*	0.221	0.916	1.00	1.23
WR	0.158	0.873	1.00	1.38

*Indica Rice : tested at $\sigma_{V'}$ = 1 kPa; the others at $\sigma_{V'}$ = 2 kPa

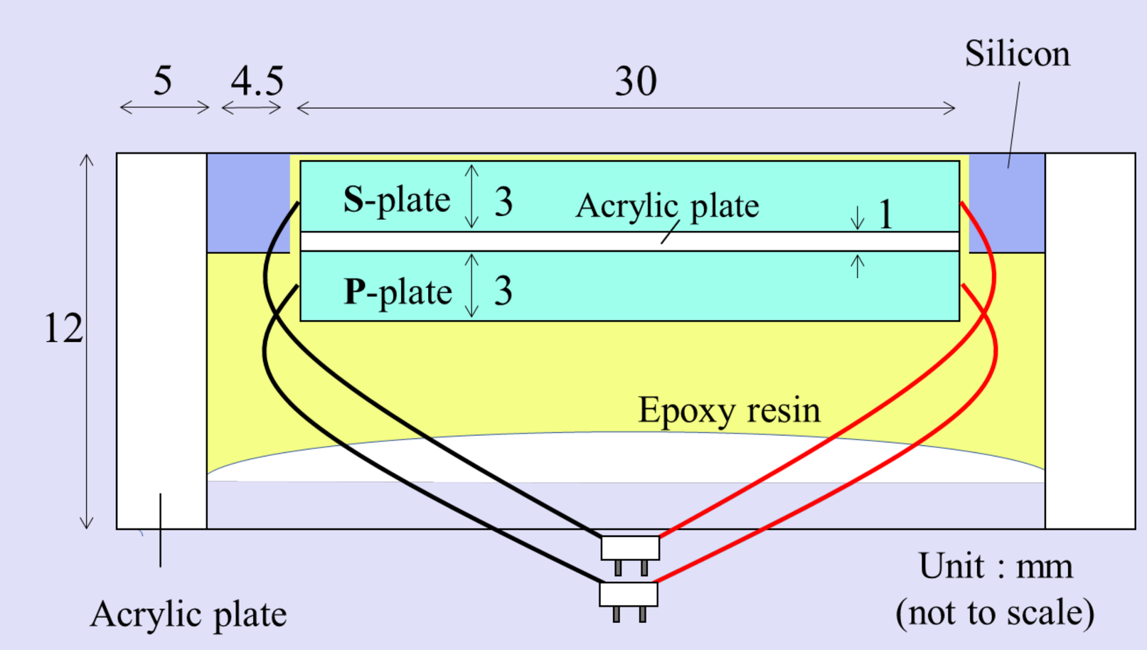
(3) Cubical Soil Box and Shear Plate Configuration

A cubical soil box made of acrylic plates was assembled (100×100×100 mm.) Each face of the soil box had a square hole and it can facilitate an assembly of shear plate transducers


Cubical Soil Box



Shear Plate Transducer

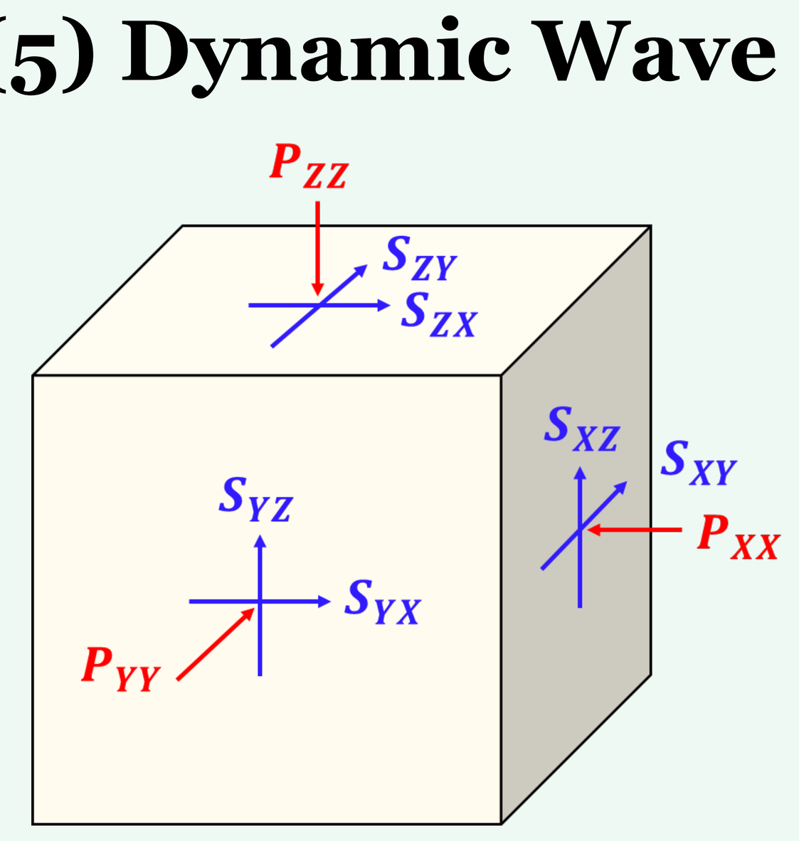


Schematic of design configuration of shear plate

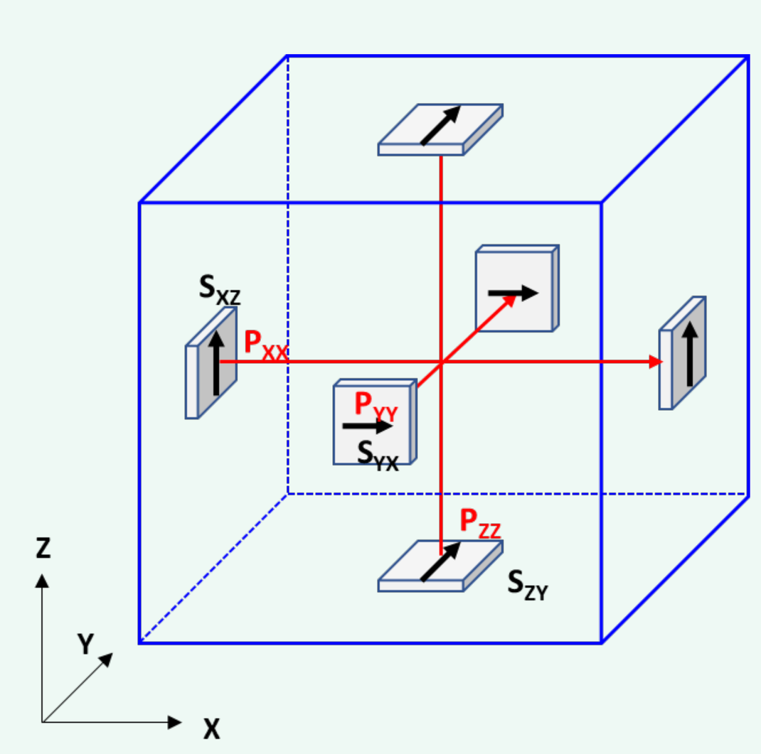
(4) Sample Preparation

- The materials were pluviated into the soil box with a dry condition.
- The height of each layer was approx. 10 cm.
- Wave measurements were conducted at three stress levels: $\sigma_{V'}$ = 0.3, 1 and 2 kPa.

(5) Dynamic Wave Propagation Tests



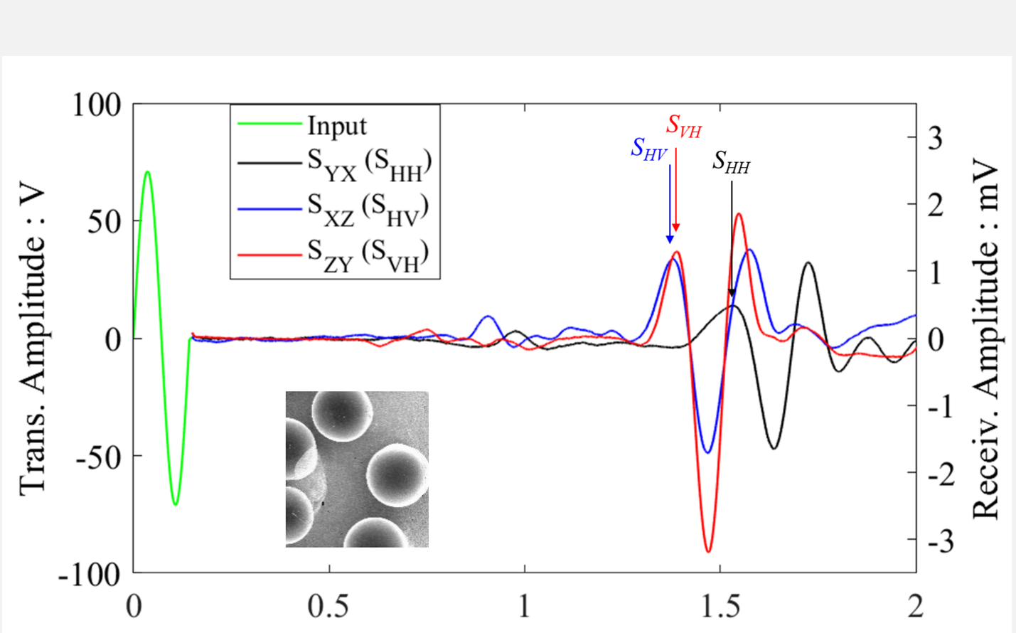
- There are nine types of elastic wave components as illustrated the left hand.
- The first subscript indicates the direction of wave propagation and the second subscript corresponds to the direction of wave oscillation.

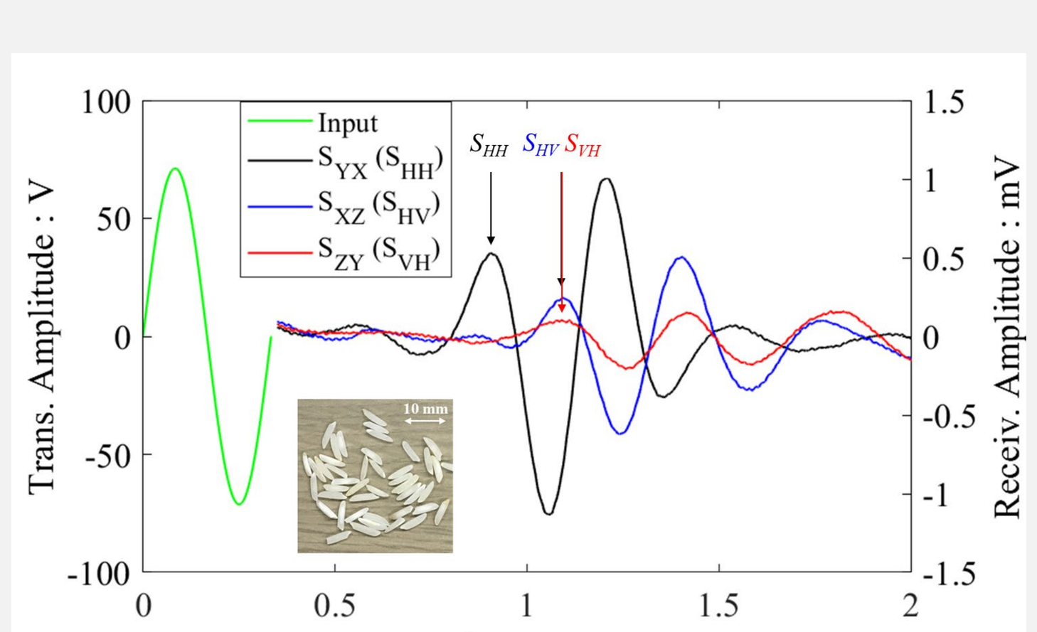


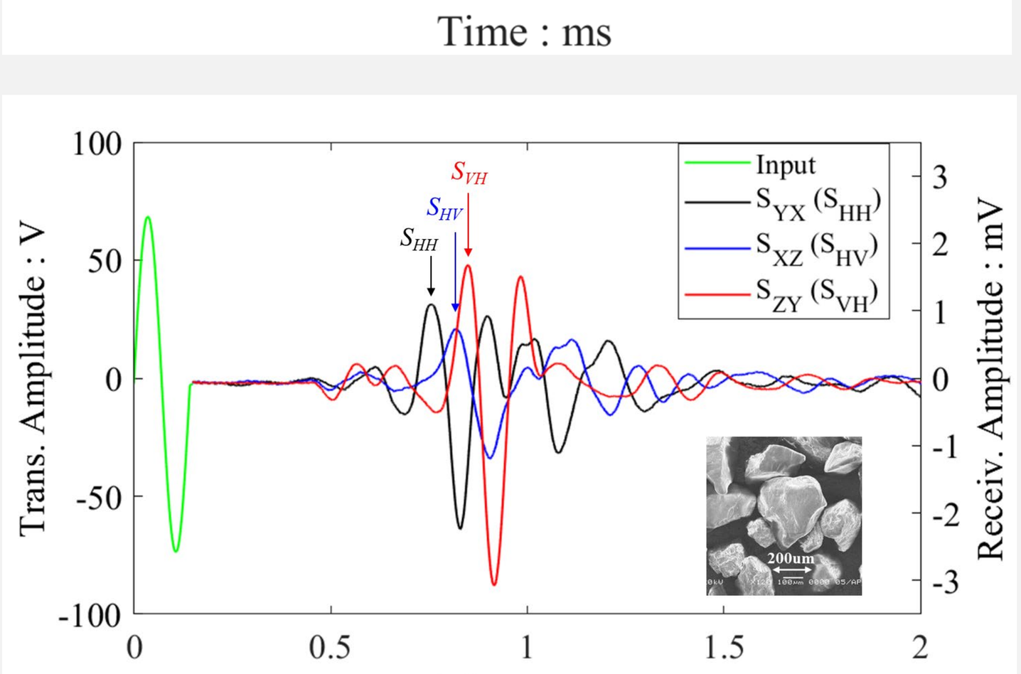
- The present test setup provides three types of P-waves, i.e. P_{XX}, P_{YY} and P_{ZZ}, and three types of S-waves, i.e. S_{YX}, S_{XZ} and S_{ZY}
- Homogeneous distribution of particle orientation in the horizontal plane is assumed. Horizontal components are expressed as H, while Z components are expressed as V. Therefore, the three S-wave components are S_{HH}, S_{HV} and S_{VH}.

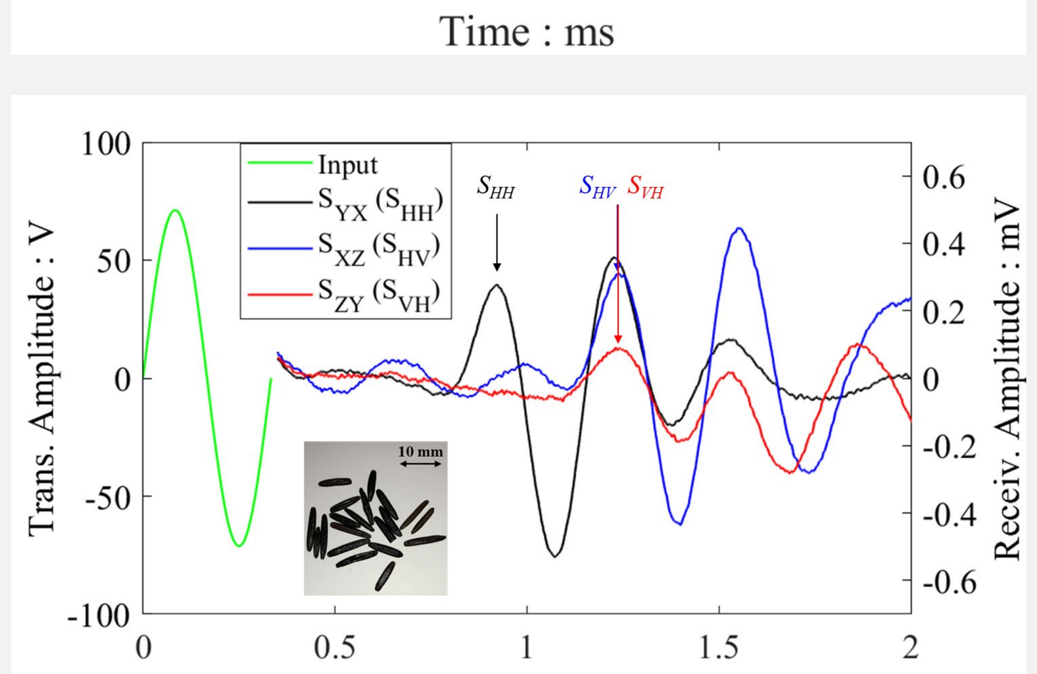
(6) Experimental Results

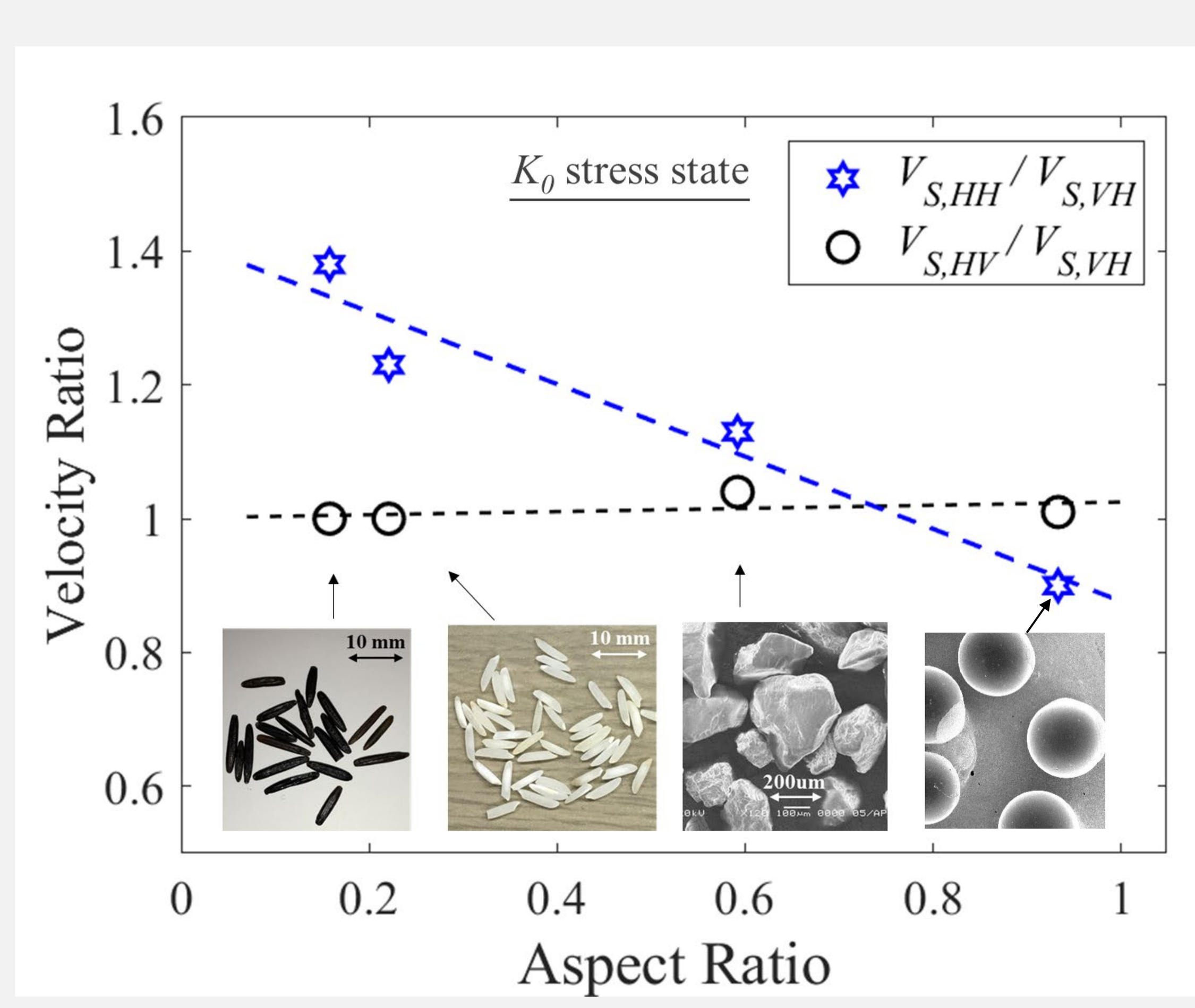
The results focus only on S-wave signals to discuss the anisotropy of shear wave velocities.











- A decreasing trend of $V_{S,HH}/V_{S,VH}$ is observed for increased aspect ratio. The maximum value of $V_{S,HH}/V_{S,VH}$ is 1.38 for wild rice.
- $V_{S,HH}$ > $V_{S,VH}$ in general. Only spherical glass bead shows $V_{S,VH}$ > $V_{S,HH}$, probably due to larger stress in the vertical direction with insignificant inherent anisotropy of the specimen.
- The symmetry components, $V_{S,HV}$ ≒ $V_{S,VH}$ under K_0 stress states .

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