Reflection of surface waves by fault structures in granular media

Raf Martens, Jasper Smits, Ivan Vasconcelos, Ernst Willingshofer, Fred Beekman

Introduction

Analogue models are frequently used to study geological processes and gain qualitative and quantitative insight into the evolution of large scale deformation. Approximating fault structures in the brittle regime is often done using a model with a granular medium. This type of model is however difficult to study directly. Recently advances have been made in studying the internal structure of granular media without disturbing the experiment, using either x-ray tomography or acoustic imaging. In this project we studied whether a new method of laser induced acoustic imaging is viable for imaging the internal structure of a granular medium. To determine this we studied the propagation of acoustic waves, and it's interaction with a deformation zone, including the influence of the deformation zone properties and geometry.

Experimental set up

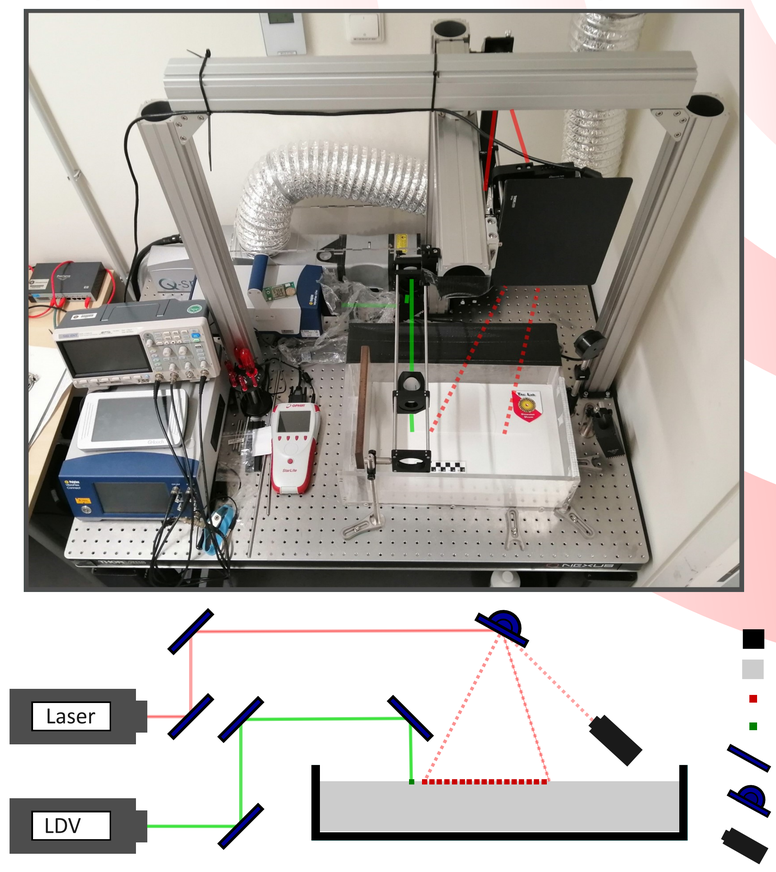


Figure 1: Overview of the physical modelling measurement set-up. A picture of the vibrometry set-up in the lab and a schematic view of the laser vibrometry system. The paths of the Laser and the laser doppler vibrometer(LDV) are indicated in red and green respectively. The mirror + rotational stepper motor allows the laser to be aimed at different location on the model.

Main results

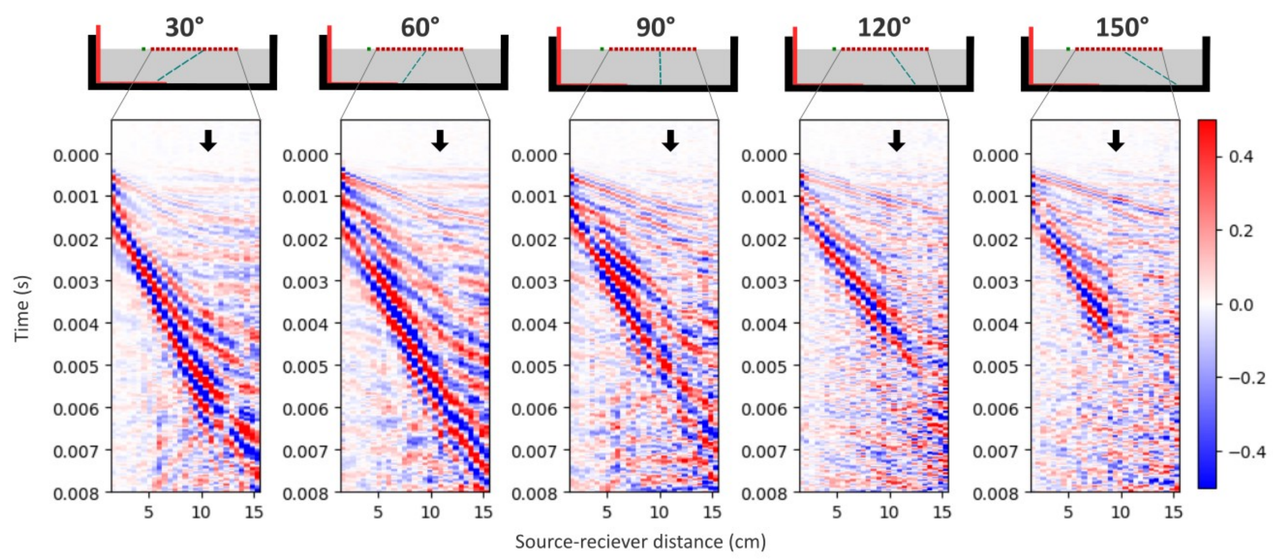


Figure 2: Acoustic profiles for deformation zones with different geometry. The black arrow indicates the position of the deformation zone. A schematic cross section of the corresponding fault structure is imaged above the corresponding acoustic profiles.

Granular media wave behaviour

Wave behaviour in granular material differs significantly with regular solid materials. This difference is caused by a heterogenous wave velocity throughout the material, according to the following equation (Bergamo and Socco, 2016):

$$V_{P,S} = \gamma_{P,S}(\rho g z)^{\alpha_{P,S}}$$

Where γ P,S and α P,S are coefficients for either p- or s-waves. ρ is the bulk density, g is gravity and z is the depth.

Surface wave reflection

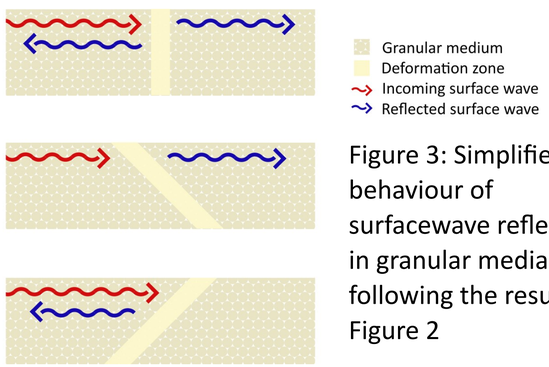


Figure 3: Simplified behaviour of surfacewave reflections in granular media following the results in Figure 2

Conclusions:

- Deformation zones can be distinguished based on laser induced surface waves.
- The geometry of a deformation zone affects the surface wave reflection based on:
  - the dip direction
  - The deformation zone thickness
- Imaging deeper internal structures requires improvement to the method

Acoustic profile

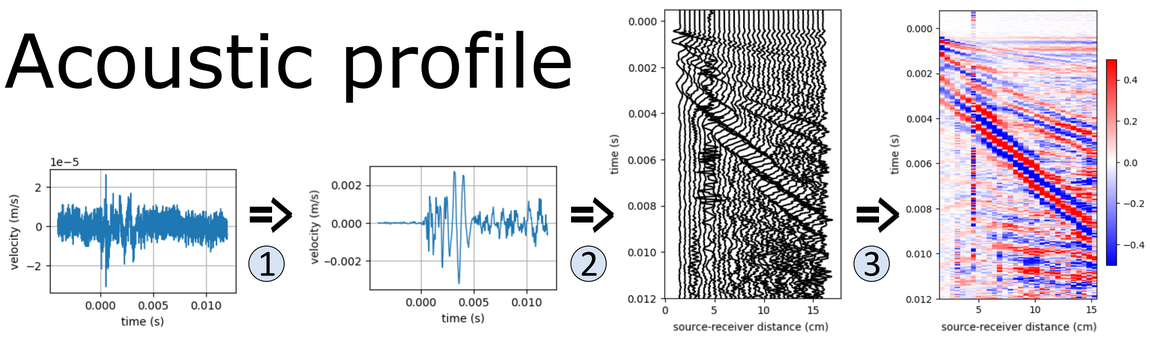
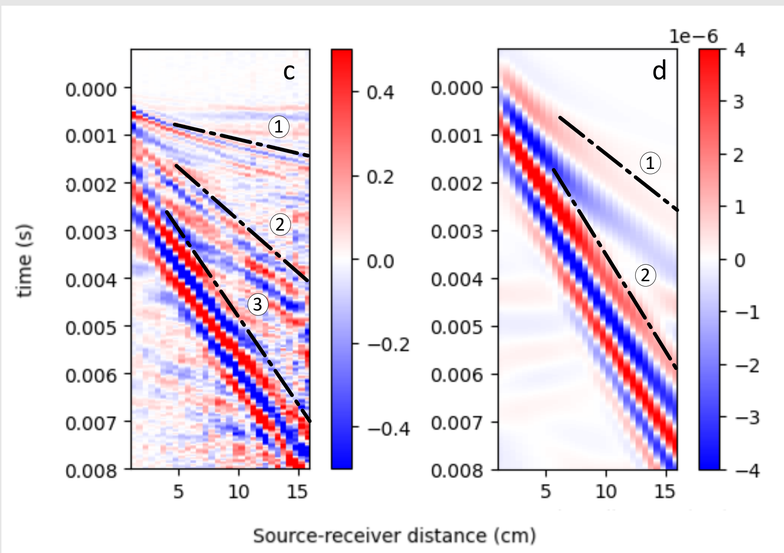


Figure 4: The three steps to create an acoustic profile:

1. 20 traces are averaged, filtered using a bandpass filter and gained.
2. combining the traces of all source point together in a wiggle plot.
3. The individual traces are then plotted as a density plot.

Numerical modelling



The experiments were recretaed using numerical modelling based on the wave behaviour in a granular medium

The numerical modelling results supported the conclusions of the physical experiments.

first arrival of wave types:
1. P wave
2. P-SV wave 1
3. P-SV wave 2

References:
Bergamo, P. and Socco, L.V., 2016. P-and S-wave velocity models of shallow dry sand formations from surface wave multimodal inversionVP and VS model of dry sand with SW. Geophysics, 81(4), pp.R197-R209.