Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

STT56-01 Room:203 Time:May 20 15:30-15:45

Electromagnetic scattering by fine ceramic spheres and scattering-induced suppression of insolation heating

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1.INTRODUCTION

After the earthquake and the nuclear power plant accident happened in 2011 in Japan, there has been a fatal electric power shortage problem in summer due to the great demand for energy, especially for air-conditioning. It is of key importance to cut the demand and to save energy. In fact, the temperature of materials rises when they are exposed to the sunlight (insolation heating). Insolation heating could be suppressed when the materials are coated with paint admixed with fine silica spheres. Coating buildings' walls and roofs with such paint, the temperature in rooms could be kept lower without using air-conditioner. This phenomenon is well known and has even been utilized in the past, but has hardly been analyzed theoretically yet. Theoretical analysis would greatly enhance its effect of the suppression of insolation heating.

We focus on the light scattering by fine spheres assuming that the scattering causes the phenomena. Mie scattering theory might be dominant for the scattering of infrared radiation by the spheres used in the paint. We calculate the intensity of total waves which pass through the paint layer using Mie theory and investigate how the structure of the paint attributes to the intensity.

2. METHOD

In this study, we considered three layers: air, paint (fine silica spheres are randomly distributed in this layer), and iron. We assumed a plane electromagnetic wave whose amplitude was unity and evaluated the total intensity of the transmitted waves, which were supposed to be the transmitted incident wave and scattered wave from each sphere. We used Fresnel equations for reflection and transmission of a plane wave which incidented on a boundary between two layers, and Mie theory for the scattering of a plane wave by fine spheres.

We used four models. The size of the spheres for each model was as follows: (a)0.5, (b)0.4, (c)0.3 and (d)0.2~0.6 (in line with the Gaussian distribution) micrometer. The wavelength of the incident wave was assumed to be largely near infrared band (0.5~2.5 micrometer).

3. Result

We calculated the total intensity of the transmitted waves for every wavelength. The total intensity of the transmitted waves turned out to get minimum when the wavelength of the incident wave was near the spheres' diameters. This suggests that specific wavelength could be selectively weakened by specific size of spheres. Moreover, there was little difference of the intensity distributions between model (c) and (d). This implies that scattering characteristic of the average size of spheres could be obtained even in case of various sizes of spheres.

4.Summary

Our goal is to analyze light scattering to find most efficient structure of the scatterer. We supposed fine silica spheres randomly distributed in a paint layer and calculated the total intensity of transmitted waves.

We found that specific wavelength could be selectively weakened by specific size of spheres and that scattering characteristic of the average size of spheres could be obtained even in case of various sizes of spheres. These facts would be useful to carry this study on to apply the results of this study to the practical paint.

Keywords: scattering, electromagnetic wave, ceramic sphere, Mie scattering, energy saving, insolation heating

STT56-02 Room:203 Time:May 20 15:45-16:00

Seismic wave simulation in fractured media using a particle method

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The seismic wave propagation in fractured media with a particle method is presented. We use a Hamiltonian Particle Method (HPM) to simulate seismic wave propagation. It is easy to implement discontinuities in the particle method without numerical instability. Furthermore, spatial resolution can be improved only by dividing particles.

We simulate seismic wave propagation in a model with a random oriented single fracture, and implement arbitrary refinement technique to the model. The results are compared with the analytical solutions, and show good agreement with those. Next, we model the propagation of a plane wave through a well-defined fractured region. The results show good agreement with the formulae for effective moduli from existing theories. Our results show that the method is effective to simulate seismic wave propagation in fractured media.

Keywords: particle method, numerical simulation, fractured media, seismic wave propagation

STT56-03 Room:203 Time:May 20 16:00-16:15

Simultaneous and independent generation of P and S phases using rotational seismic source (ACROSS)

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1. Introduction

The time-lapse study in focal zone along the subducting plate boundary and volcanic area is extremely important in geophysics and P and S waves are very useful to trace the physical changes of the target zones. For this purpose, we propose use of seismic ACROSS which generates forces by rotation of eccentric mass controlled by GPS time base. The rotational speed varies according to the up-and-down sweep between minimum and maximum frequencies within a certain time window. The current seismic ACROSS changes the rotational direction at an interval of one hour. Most of the existing ACROSS units typically has vertical rotational axis which generates radial and transverse forces, and the most of energy travels as S wave. However, we like to generate P and S simultaneously, so that we consider to adopt the ACROSS source with horizontal rotational axis.

2. Calculation of transfer functions for vertical and horizontal forces

The arithmetic operation of the data observed for the normal and reverse rotation provides the synthetic observation of the single forces for two orthogonal directions.

The position of the center of gravity of the eccentric mass is represented as r(t)=[x,y,z]=[Rcos q(t),Rsin q(t),0], where z is the direction of the motor axis, x is downward, y is the horizontal direction orthogonal to the motor axis, R is the rotation radius of the mass, and q(t) is the time function of phase angle designed for the source operation.

The centrifugal force generated by the mass is $F(t)=-Md^2r(t)/dt^2$ whose Fourier transform is $F(w)=MRw^2[C(w),S(w),0]$. C(w) and S(w) denote the Fourier transform of cos q(t) and sin q(t), respectively. For the reverse rotation, the phase function becomes -q(t) and the force spectrum is $F^-(w)=MRw^2[C(w),-S(w),0]$. We write F for the normal rotation as F^+.

Assuming the linear system U(w)=H(w)F(w) whose input is the force at the source and output is ground motion at the receiver. U is the 3-component vector of displacement or velocity, and H is the second order tensor of the transfer function, which we are to determine. Decomposing the tensor H into three vectors Hx,Hy,Hz, the equation can be rewritten as U(w)=Hx(w)Fx(w)+Hy(w)Fy(w)+Hx(w)Fz(w).

According to this description, the spectra of the ground motion caused by the normal and reverse rotations are

$U^+(w)=H(w)F^+(w)=MRw^2\{Hx(w)C(w)+Hy(w)S(w)\}$,

$U^-(w)=H(w)F^-(w)=MRw^2\{Hx(w)C(w)-Hy(w)S(w)\}$.

Therefore, the transfer functions can be calculated by

$Hx(w)=\{U^+(w)+U^-(w)\}/\{MRw^2C(w)\}$, $Hy(w)=\{U^+(w)-U^-(w)\}/\{MRw^2S(w)\}$.

Note that Hz is unable to be measured by rotation-type ACROSS. The waveforms in time domain are calculated by inverse Fourier transform.

3. Field experiment and its results

In February and March, 2011, we carried out a field experiment of time lapse in Japan to prove the effectiveness of our time lapse method using a newly developed seismic ACROSS-H with the horizontal rotational axis. We used 32 surface and one 800m-borehole stations. Combining of observed records for normal and reverse rotations, we calculated transfer functions for vertical and horizontal forces, respectively. In the UD component at station #7, the P and S arrivals appears at 0.2 and ~0.6s, respectively. The source gather of transfer functions at the all stations are generated. For vertical force P waves are clearly identified, whereas S waves dominate for horizontal force. This result confirms that the transfer functions for vertical and horizontal forces are successfully calculated from the observation records of the normal and reverse rotations of the ACROSS.

4. Conclusions

P and S waves distinctively dominates for calculated vertical and horizontal forces, respectively, so that it is possible to investigate the temporal variations in the propagation manner of P and S waves separately.

Acknowledgments

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Keywords: P-wave, S-wave, Rotational Source, PS, Simultaneous generation, ACROSS

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On the system correction for CCA method using simple moving coil type seismometers

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It has been known that CCA method (Cho et al. 2006; Tada et al. 2006; etc.) can determine the dispersion relation of Rayleigh waves, of which wavelength is tens or hundreds time the radius of the miniature array deployed for microtremor observation. It is easily imagined that accurate detection of phase and amplitude difference among signals from different seismometers in case of observation using a miniature array. Unfortunately the characteristics of simple moving coil type seismometers are not so accurately regulated by manufacturers as required for observation using miniature arrays. It is also recommendable to take very local amplification effect of the shallowest soil just below seismometers and also the effect of installation condition of seismometers into account. I will show the formulation shown below for the system correction using microtremor records themselves and those of huddle test, and also some results of field experiments to validate it. It is imagined that this formulation can perform the system correction if the following two conditions are fulfilled: i) All seismometers have common power spectra of input ground motion except very local amplification effect, ii) The phase difference among channels due to the installation situation and the very local amplification effect is negligible. The latter suggests that a careful installation of seismometers, e.g., using horizontal table with spirit level, is necessary in field observation. It is imagined that the abrupt change of phase characteristics around the natural period should be suppressed using appropriate shunt resistance because in site nothing but tubular or bull's eye spirit level is available tool to adjust seismometers.

Keywords: Microtremor, Miniature Array, System Correction, Dispersion Curve, coherence

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<<Formulation>> The following interim quantity $R_{ik}(f)$ is used in place of the cross-spectra of observed records $C_{ik}^{obs}(f)$ in order to calculate CCA coefficient in the frequency domain.

$$R_{ik}(f) = C_{00}^{obs}(f) \cdot C_{ik}^{obs}(f) \cdot \overline{Cor_{ik}^{huddle}(f)} \Big/ \sqrt{C_{ii}^{obs}(f) \cdot C_{kk}^{obs}(f)}$$

where $C_{00}^{obs}(f)$ denotes the power-spectra of the representative channel used as a band-pass-filter,

$$\overline{Cor_{ik}^{huddle}(f)} = \exp\left\{(j/N)\sum Arg\left(\sqrt{C_{ii}^{huddle}(f) \cdot C_{kk}^{huddle}(f)} \Big/ C_{ik}^{huddle}(f)\right)\right\}$$

the correction factor calculated from the records of huddle test, where j denotes the imaginary unit, the summation is taken over the time blocks of the huddle test records. Under the above mentioned two conditions the approximation $R_{ik}(f) \approx \left\{C_{00}^{obs}(f)/P(f)\right\} \cdot C_{ik}(f)$ can be taken, where $P(f)$ denotes the power-spectra of the input ground motion common to all channels. Then, CCA coefficient can be calculated using $R_{ik}(f)$ as shown below.

$$\sigma_{CCA} = \frac{\sum C_{ik}(f)}{\sum C_{ik}(f)\exp\{-j(\alpha_i - \alpha_k)\}} \approx \frac{\sum R_{ik}(f)}{\sum R_{ik}(f)\exp\{-j(\alpha_i - \alpha_k)\}}$$

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Change of the near-surface geophysical properties along levee systems before and after the 2011 East Japan Earthquake

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Levee systems in Kanto Region, central Japan, were severely damaged at many places caused by the long-lasting strong ground motion of the magnitude (Mw) 9.0 East Japan Earthquake, which occurred at 14:46 JST on Friday, 2011 March 11, even located more than 200 km far from the epicenter. Since 2005, we have conducted integrated geophysical surveying for the safety assessment of levee systems at 39 actual levee sites in Japan. Among them, severe damage took place in two sites by the East Japan Earthquake just at the anomaly part delineated by the survey. The anomaly part in one site was characterized as low S-wave velocity and low resistivity both for levee body and substrata. After the Earthquake, we conducted comparative surveying on the same levee but the damaged part of which had been soon repaired. As a result, the characteristic low S-wave velocity and low resistivity zone was again identified just at the damaged or repaired part where substantial top subsidence had occurred. This suggests a physical model that nonlinear loosening of underlying clay layers had caused the ground failures and resulted in the damage of levee systems. The other site, where large sliding had taken place on a river side levee slope during the earthquake attack, was featured by the existence of high resistivity anomaly in the levee body. The anomaly was also identified by the comparative surveying at the same part where the slope sliding had occurred. A different type of levee failure mechanism was interpreted as resulting from high contrast of physical properties in levee body, based on our integrated geophysical surveys. Thus the corresponding survey results lead us to the usefulness of the integrated geophysical surveying for understanding levee failure mechanism and for the assessment of present conditions of levee systems attacked by the Earthquake.

Keywords: East Japan Earthquake, geophysical survey, levee system, change in geophysical properties