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

Japan Geoscience Union Meeting 2012
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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

Japan Geoscience Union Meeting 2012
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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

This study has been supported by JCCP.

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

Japan Geoscience Union Meeting 2012
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STT56-04 Room:203 Time:May 20 16:15-16:30

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

<<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,

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

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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STT56-05 Room:203 Time:May 20 16:30-16:45

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

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STT56-P01 Room:Convention Hall Time:May 20 15:30-15:45

Modeling Real Structure with FDM using In-equally Spaced Grids - Effects of Seafloor Topography on Tsunami Propagation-

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When we use numerical simulation to understand geophysical phenomena, topography often affects those phenomena. It is necessary for understanding them to explain those phenomena in realistic structure models. In this study, we consider to use the Finite Difference Method (FDM) with in-equally spaced grids as a method for modeling realistic structures. We apply our method to tsunami disaster mitigation, considering the effects of the seafloor topography on the tsunami propagation.

Tsunami simulations are widely used to predict tsunami behavior occurred by an earthquake. The simulated tsunami, however, does not show good agreement with the observed one so often, especially in later phases. In this study, we make a hypothesis; the simulation of tsunami propagation including the effects of the seafloor topography can solve the difficulty of prediction of tsunami in later phases. We simulated tsunami propagation by solving three dimensional Navier-Stokes equations and by using FDM with in-equally spaced grids for realistic seafloor topography model. Comparing tsunami propagation in our method with that based on the conventional long wave theory, we discuss the effects of seafloor topography on tsunami propagation. We find that the tsunami propagation is influenced by two effects; effects of real changes in water depths and those of nonlinear terms in N-S equations. As a result, we conclude that our method, considering realistic seafloor topography on tsunami propagation, leads to the prediction of tsunami including later phases with much higher accuracy than the present.

Keywords: simulation of tsunami propagation, seafloor topography, modeling, in-equally spaced grids, later phases of tsunami, The Tohoku earthquake

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STT56-P02 Room:Convention Hall Time:May 20 15:30-15:45

The application of the fullwave inversion techniques to Ocean Acoustic Tomography

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The problem of Ocean Acoustic Tomography (OAT) is to estimate the state of ocean in temperature, salinity, etc. that are related to sound velocity structure from the travel-time or other properties in acoustic wave propagation. The ocean is nearly transparent for low frequency acoustic waves so that the acoustic wave could propagate for thousands of kms. OAT was first introduced by Munk et al. (1995) and based on a ray theoretical approach. A travel-time inversion method has been developed using a ray-tracing scheme in the Munk's method. There is some similarity with seismic exploration both in theory and in data processing methods. However the waveform analysis is not common in OAT although its importance is widely recognized in seismic explorations. Actually there is hardly any precedent studies on waveform inversion in the application of OAT. In this study, a full-wave inversion technique is applied to OAT in the 2-D acoustic FDTD model in order to investigate the effectiveness of the method through the comparison of the results with that of the ray-tracing inversion approach. Then, as an application for a field data, the full-wave inversion technique is applied to the VCS experiment data in Lake Biwa. The result shows applicability of the full-wave inversion technique to OAT and also shows that full-wave inversion provides higher image construction than in travel-times inversions.

Keywords: Underwater acoustic, VSC, Full-wave inversion, Ocean Acoustic Tomography

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STT56-P03 Room:Convention Hall Time:May 20 15:30-15:45

Relationship between formation of parallel faults and stress fields in rock mass

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Some parallel cracks and faults, which are caused by earthquakes and crustal deformations, can be observed as various sizes from crustal scale to laboratory scale. The mechanism of formation of these parallel faults is not well investigated, and there still remains an important geophysical subject. If we find the relationship between the formation of parallel faults and stress field applied to rock mass, we could infer stress field loaded to the crust from the pattern of faults. For interpretation of these cracks behaviors, many attempts have been made using fracture mechanics theory. These attempts have successfully represented the propagation of predefined cracks. However, it is difficult to describe the initiation and the coalescence of cracks using this theory. Thus, in the recent years, numerical modeling has been applied to study crack behaviors in rocks. In this study, we conducted numerical simulations of rock mass failure under different conditions to investigate the nucleation conditions.

In this study, we use the Hamiltonian Particle Method (HPM), one of the particle methods. In the particle methods, a continuum is represented as a set of particles and a motion of the continuum is approximated as a movement of the particles. Therefore, the particle methods do not need the calculation grids or elements and can describe the failure at faults or cracks. We assumed that a rock mass with rectangular shape consists of basalt. The calculation model is based on a three dimensional elastic body. The failure of rock mass is assumed to obey the Mohr-Coulomb failure criterion and the tensile and compressive strength of rock elements distribute following the Weibull distribution. As stress fields in rock mass, we applied compressive, shear and bending forces to rock mass and changed the direction and magnitude of these forces. Results of the simulations suggest that the confining pressure would have dominant influence for the initiation of parallel faults in compressive conditions and that the shear force would provoke the propagation of parallel fractures along the shear direction.

Keywords: fault, particle method

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11 years long term monitoring of Seismic velocity near Nojima fault using ACROSS

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We have conducted a monitoring experiment of near fault seismic velocity for 11 years using an accurately controlled seismic signal system named ACROSS.

The aim of our study is to monitor the healing process of the fault after the rupture by the 1995 Kobe earthquake (M7.3) using ACROSS. The name ACROSS stands for Accurately Controlled and Routinely Operated Signal System, which continuously generate controlled seismic wave by centrifugal force from mass rotation. We deployed a couple of ACROSS sources in a source house just 300m away from the fault surface and the seismic signal generated by them is received by seismometers deployed at the bottom of 800m- and 1700m-deep boreholes just beneath the sources. The two sources are designed to generate same force of $2x10^5$N by different rotation frequency of 25Hz and 35Hz respectively.

In this study, the source operation was repeated intermittently for 11 years from 2000 to 2012. We monitored the following three elements of the signal.

1. Travel time and amplitude of P and S waves. The both waves advanced about 4 per mill in the 11 years.
2. Travel time of S-coda phases. The coda part showed velocity increase (travel time advance) for 1 per mill, smaller than that of body waves.
3. S-wave splitting. The difference of velocity has been 10 % between the two S waves in the orthogonal vibration directions through the measurement period. The difference did not change to the detectable level.

If we assume the cause of the travel time advance to be a reduction of the crack density, the value is calculated to be 0.004-0.01 assuming random coin-shape crack. Previous studies reported that the permeability around the 1700m-deep borehole decreased by 50 per cent from 2000 to 2007. The decrease of the crack density qualitatively explains the permeability change. However, the permeability changed drastically while the change of the crack density is very small. This suggests that just disconnection or sealing of the water channels occurs without large change of crack density.

Keywords: ACROSS, Nojima Fault, Fault-zone Probe, Seismic velocity, Monitoring

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STT56-P05 Room:Convention Hall Time:May 20 15:30-15:45

The measurement of soil water content of upper part of the cave using electromagnetic component of air shower

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We have developed a new radiographic method to measure the time variation of the water content of the soil with soft component of air shower.

Air shower produced by a primary cosmic ray consists of hard component and soft component. Hard component is mainly consists of muon, and soft components is consists of electron, positron and photon. The penetration power of soft component is weaker than that of hard component, so soft component is suitable for small scale structure thinner than 2 kg/cm2 equivalent to 20m thick water, like buildings and small hills. But it requires particle identification which means distinguishing hard component and soft component. Particle identification can be done with strong magnets and dense detectors, but it is very hard to use that kind of detector for radiography because of their weight and cost.

We established the cheap and effective method to distinguish soft component and hard component statistically. We also performed measurements in Arimura observation pit of Mt. Sakurajima, Japan. As a result of this observation, we found there is an anti-correlation between soft component flux and rainfall. If the water content of the soil became larger, the amount of absorption increases. So this result can be interpreted as detecting the increase of the water content by soft component flux.

This method can be applied for the quantitive compensation of the measurement data like absolute gravitymeter data and tiltmeter data which is easy to receive turbulence by rain. It is also expected that the quantitive compensation leads to the improvement in accuracy of diastrophism measurement and the improvement in presumed accuracy of magma movement inside a volcano.

Keywords: soil water content, cosmic ray, radiography

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Analysis of electromagnetic data by using MT frequency response function, application of geophysical exploration

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Electromagnetic inductive response, produced by electromagnetic variation in ionosphere or magnetosphere, is mainly included in observed electromagnetic data in the earth surface. The inductive response is used for the estimation of resistivity structure such as a MT method. The inductive effect is made by solar activity which varies widely cyclic or irregularly, and the observed electromagnetic data also vary widely. Therefore, the inductive response becomes obstructive factor in analyzing water injection or CO2 storage experiment in the real field. Recently, we attempt to remove the inductive effect on time-series electromagnetic data by using MT frequency response function. This method is able to estimate inductive effect on time-series electric data from magnetic data, or magnetic data from electric data. If the inductive effect on observed electromagnetic data can be removed by the method, the target signal should be clearly picked out. We will present the results of the analysis of observed MT time-series data.

Keywords: MT method, frequency response function, geophysical exploration, analysis of time-domain data

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STT56-P07 Room:Convention Hall Time:May 20 15:30-15:45

Improvement of prospecting accuracy of subsurface structure by GPR using polarization and transmitted waves

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Visualization techniques of the subsurface structure using the electromagnetic waves have been used widely in many fields such as detecting underground pipe, existences of underground cave and fractures that can cause subsidence, excavation of archeological site, estimating geological structure, and natural resource exploration. Estimating subsurface physical properties such as dielectricity, electric conductivity, and magnetic permeability is indispensable to improve the prospecting accuracy, which can contribute to identify the subsurface materials in addition to geometrical properties of material boundaries. However, it is difficult to estimate such subsurface properties at the present because of strong heterogeneity concerning physical properties distribution and shape of stratum boundary.

For this problem, we developed a prototype system of Ground Penetrating Radar (GPR), termed POGRA (POlarimetry Ground penetration RAdar system) which separates transmission and receiving antennas. The merit of POGRA is that it can measure two types of microwaves: transmitted waves and two or more polarization waves by the arrangement of antennas. Transmission-type GPR (T-GPR) can receive the input signals more strongly than the traditional reflection-type GPR by reducing the travel distance of microwaves by half. Capability of the T-GPR was tested for a structure with caves under the water table: the T-GPR could detect the caves correctly. For a horizontal layer structure, geological box model was produced using many small boxes filled with sands whose dielectricity values were set as large, middle, and small by changing the water content. Polarization-type GPR (P-GPR) was applied to three layers structure, and dielectricity values of each layer were calculated. It was clarified that the dielectricity values could be obtained correctly for the structure in which the dielectricity increased with the depth.

Keywords: Dielectricity, Fresnel equations, Reflection coefficient, Transmittance, Geological model