Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS33-P01 Room:Convention Hall Time:May 19 18:15-19:30

Newly developed 3D velocity structure model of the Osaka sedimentary basin

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Three dimensional subsurface structure model of the Osaka sedimentary basin is revised with additional survey data conducted under Comprehensive Research on the Uemachi Fault Zone (FY2010-2012) by MEXT. We improved the three-dimensional basin velocity model by adding new observations and applying newly developed methodology to describe the three-dimensional model under the Comprehensive Research Project on the Uemachi Fault Zone by MEXT.

3D velocity structure models have been developed for the Osaka sedimentary basin from earlier time than in other areas thanks to relatively dense data of underground structure surveys. Former 3D models are classified into two types. One, we call them J-type here, includes Kagawa et al.(1993), Miyakoshi et al.(1997), Miyakoshi et al.(1999), Kagawa et al.(2002), Iwata et al.(2008) and Iwaki and Iwata (2011). Another one, H-type, includes AIST model (Horikawa et al., 2003) and Osaka Prefecture model (Osaka Prefecture, 2004). These two types adopt quite different description of their 3D structure. J-type models divide the sediments into three layers with constant Vp, Vs and densities and adopt spline-function to model the layer boundaries, which make it easy to derive medium properties at arbitrary point. H-type models are given in fixed 3D grids to express complex heterogeneity and steep material-boundaries like overhang faults. Medium properties are given by empirical formulas depending on the depth and the depositional age which were constructed based on geophysical prospection data.

In this study, we aimed to model the layers and medium property structure as faithful as possible to survey data (like H-type models) and to describe the layer boundaries by interpolation functions so that we can get the model in arbitrary mesh (like J-type models). To realize this, we construct our 3D velocity structure model with the following way.

1) Divide the model area by extreme boundaries like faults
2) Describe the layer boundaries by appropriate interpolation functions
3) Prepare the empirical formula for medium properties which depends on depth, depositional age and regionality
4) Prepare dataset and tools to calculate relative location to layer boundaries and block boundaries and to calculate physical properties for given point or given arbitrary mesh

In order to get information to improve the velocity structure, we have conducted the microtremor array observation for obtaining phase velocities at 6 sites in southern part of the Osaka basin, single-station microtremor observation for obtaining H/V spectra at 100 strong motion stations, continuous microtremor observation at 15 stations and seismic interferometry, and the reflection survey along 2 lines. We also collected strong motion records from seismic intensity observation network by Osaka prefectural government and other strong motion networks (CEORKA, K-NET, KiK-net, etc.), and used them to estimate PS-P travel time by the receiver function analysis and to compare with the synthetic waveforms of moderate size events. We found that the velocity structure model needed improvement especially in the southeast of the basin, southern part of the Osaka Bay area, and northern edge of the basin. We made necessary modification to empirical formula for medium properties and depths of layer boundaries.

Keywords: layer boundary, empirical formula for medium properties, physical prospecting, microtremor

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Development of estimation method of deep ground structure using long-term microtremor observation and gravity survey

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The purpose of this study is to develop an easy way to estimate deep ground structure. We combine gravity survey and long-term microtremor survey. Seismic interferometry is applied to analyze long-period microtremor, where the influence of deep soil structure appears. Our method is applied to the case in Hsinchu, Taiwan and structure model is modified.

Keywords: long-term microtremor observation, gravity survay, seismic interferometry, deep ground structure

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Estimation of vibration mode of Mt. Fuji from microtremor measurements

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Natural frequency is one of the important characteristics which are determined with physical properties and geometry in subsurface structure including mountains. In particular Monitoring of natural frequency for active volcanic mountain can facilitate our understanding of its dynamic change, such as the intrusion of magma for prediction of the eruption.

In this study, we verify if we can estimate the frequency characteristics of Mt Fuji, the highest mountain in Japan, with microtremor observation. The microtremor observation was conducted from 6 to 9 August 2012. 7 locations are prepared in the observation at the 2nd and from the 5th to the 10th stations of Mt.Fuji. We temporarily installed a three-component accelerometer and a data logger at each station.

In the analysis, we made a spectral analysis of the observed records, and we found the predominant frequency around 0.2 Hz in the NS component. Amplitude distribution at this frequency is similar to fundamental mode shape of vibration. However, the vibration at the 6th station at the predominant frequency shows slight different features. We confirm from a cross-correlation function in the vicinity of the predominant frequency that delay time between the 6th and 10th stations is greater than others. The result suggests the vibration mode changes near the boundary of the 6th station of Mt.Fuji. This feature of the vibration may be related with the subsurface structural changes around there, because it is located near the boundary of Older Fuji and Younger Fuji or it is close to the volcano Hoei. We need to discuss this from long-term observation data.

We also conducted eigen value analysis with FEM using a simple cone model; 20km in diameter and 3km height. The first natural frequency of the model is about 0.2 Hz, and this is almost the same as the results with the observations. This shows that it is possible to estimate the frequency characteristics of Mt.Fuji with microtremor observation. However, the used model was a very simple model, and it is necessary to consider a model closer to the actual model for detailed investigation. Moreover, we need to verify how the natural frequency changes with changing the properties.

We thank participants of the observation in this study. We are also indebted to the people in the mountain hut. We would like to sincerely thank them.

Keywords: Mt.Fuji, frequency charateristics, volcano

SSS33-P04 Room:Convention Hall Time:May 19 18:15-19:30

A method to construct subsurface structure model using microtremor, gravity and magnetic data in the Tottori plain.

Yusuke Ishida[1*], Tatsuya Noguchi[1], Takao Kagawa[1], Hitoshi Morikawa[2]

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In this study, we propose a method to construct a subsurface structure model using microtremor, gravity and magnetic data in the Tottori plain. Recently, different types of physical exploration data are analyzed simultaneously to improve uniqueness and accuracy of subsurface structure model (e.g. Sakai and Morikawa, 2005).

In the target area, granite or sedimentary rock is found for seismic basement (Geological survey of Japan, 2003). The difference of densities is about 0.2t/m3 between the two rocks. Therefore we cannot perform gravity analysis with simple homogeneous two layers model, sediment layer 2.0t/m3 and seismic basement 2.4t/m3 (Noguchi et al., 2003). To overcome this problem, we employed magnetic data with the gravity data, and performed gravity analysis assuming several types of basement rocks with different densities. We applied the MWP (moving window Poisson analysis) method (Chandler et al., 1951) to get boundaries where densities change, and estimated depth distribution of seismic basement from gravity anomaly data. Based on the result, we estimated S-wave velocity structure model through inversion analysis of phase velocities of microtremor array observation data (Noguchi et al., 2003). As the result, we constructed a 3D subsurface structure model with three sedimentary layers and bedrock layer in the target area.

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Keywords: subsurface structure model, microtremor survey, gravity survey, magnetic data, MWP (moving window Poisson analysis) method, Tottori plain

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SSS33-P05 Room:Convention Hall Time:May 19 18:15-19:30

Modeling of a subsurface structure from a seismic bedrock to the ground surface for a broadband strong motion evaluation

Shigeki Senna[1*], Takahiro Maeda[1], Yoshiaki Inagaki[2], Hisanori Matsuyama[2], Hiroyuki Fujiwara[1]

[1]NIED, [2]OYO corp

We have built the structure model which can evaluate the strong ground motion characteristic of a broadband for the purpose of the advancement of strong motion evaluation. The built contents are the structure models which unify the subsurface part structure model and the deep structure model, and can reproduce seismic observation record.

In this report, the contents of examination of the structure model construction in a south Kanto area(5 prefectures except Tochigi and Gunma) and a concentrated deformation zone (Niigata, Yamagata, and Akita) area are introduced.

The final contents of examination adjusted the flow of structure model creation, and the valuation method of the periodic characteristic and the amplifying characteristic of the structure model. The result is improved for the period about 1 second in all the investigated areas.

Keywords: Velocity structure model, Microtremor survey, Strong motion evaluation, Borehole data

Japan Geoscience Union Meeting 2013
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SSS33-P06 Room:Convention Hall Time:May 19 18:15-19:30

Determination of underground structure of Palu City, Sulawesi, Indonesia by microtremor observations

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Palu City is located in the northern part of island of Sulawesi, Indonesia and there is active fault in the western part of city area. In this study, underground structures were estimated by array and single 3-componet microtremor observations. S-wave velocity structure models with 3 to 5 layers at the 10-sites were determined from array observation records. Predominant periods of H/V at 126 sites were obtained from 3-componet observation records. The S-wave velocities of alluvial layers were form 140 to 300m/s. The predominant period was about 1 second that H/V spectral ratio has clear single peak models near the coast line area. Therefore soft alluvial layer was distributed coast line area. Depth to bedrock (S-wave velocity is 600m/s layer) was about 90m maximum in the area.

Keywords: Microtremor observation, S-wave velocity structure

SSS33-P07 Room:Convention Hall Time:May 19 18:15-19:30

Development of Numerical Code for Simultaneous Estimation of Subsurface Structure with Gravity and Magnetic Data

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We present the test calculation of simultaneous estimation of subsurface structure with gravity and magnetic data. The simultaneous estimation is performed by the construction of sensitivity matrix and its inversion. For this purpose, we developed a new numerical code for solving the singular value decomposition based on I-SVD scheme. Usually, the sensitivity matrix is ill-conditioned when the number of the observation data and the model points is large. We need some regularization to solve this ill-conditioned inversion. Some technical discussion is also presented.

Method

Trial model of subsurface structure is represented by M model points, which has k layers. While each layer has fixed given value, the depth of each model point z_i is variable. We change these depth z_i to account for the gravity and magnetic anomaly at N observation data on the surface.

Forward Calculation

We starts the calculation from the plane parallel model as an initial trial model. The prism gravity and magnetic field in arc tangent form is adopted for the gravity and the force calculation. When the depth is changed at each model point, a material in a prism shape volume is replaced from the lower side to the upper side, and vice versa.
The increment of gravity and magnetic field, generated by this replacement, is added to the previous value.

Inversion Calculation

Inversion calculation is performed by the construction of sensitivity matrix and its pseudo inverse matrix. The sensitivity matrix is defined by the differentiation of gravity and the magnetic field by each model depth. As the observation data, both the gravity and the magnetic data are used simultaneously. The size of this matrix becomes NxM. We calculate the depth change of each model point to account for the data difference between the model and the observation with the pseudo inverse matrix. However, the depth change sometimes becomes quite different from the adjacent ones, which is physically inappropriate for the successive conversion. Therefore, additional constraint condition is added to the sensitivity matrix, so that $\{\text{Nabla}\}^2$ $\{\text{delta}\}$z = 0. Then, the matrix size becomes (N+M)xM. This additional condition smooths out the adjacent fluctuation.

For this purpose, we developed a new numerical code for solving the singular value decomposition based on I-SVD scheme. Our numerical code is written by Fortran 95 in double precision, except for the lowermost DO loop for singular values calculation. This part is need to be written in quadruple precision.

With this code, we can reproduce the model subsurface structure from the model gravity and the magnetic data set.

We will also present the miscellaneous techniques for matrix regularization in the poster.The inclusion and the unification of microtremor data in this code may also be presented.

Keywords: numerical calcuration, subsurface structure, singular value decomposition

SSS33-P08 Room:Convention Hall Time:May 19 18:15-19:30

Relation between S/N ratio of cross-correlation function and capability of group velocity estimation with seismic noise

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We have applied seismic interferometry to ambient noise data recorded at Hi-net stations around Chukyo area, central Japan, to estimate velocity structure of the sedimentary basin (Hayashida et al., 2012). The estimated group velocities of surface wave from the stacked cross-correlation functions (CCFs) show variations for each station pair, indicating subsurface velocity structure beneath the area and the estimated group velocities agree with the predicted ones from existing velocity structure models for many station-pairs. However, there is some difficulty in estimating group velocities for some station-pairs and it is important to evaluate its accuracies. In this study we examine the decays of signal and noise amplitudes of CCFs and the growth of signal-to-noise ratio (S/N) of the CCFs with increasing numbers of stacking. We also evaluated the relationships between the shifting patterns and interstation distances (15.2-87.7 km) and azimuths (almost all directions). The results show that the noise tends to decrease with the square root of the stacking number. On the other hand, the S/N ratios tend to increase in the first four months and remain mostly levels after that. For station pairs whose S/N ratios exceed 30, group velocities of surface waves are easily estimated. We also found that the S/N ratios sometimes exceed 100 for station pairs in an almost NNW-SSE direction. Our result indicates that group velocity of surface waves should be estimated considering the S/N patterns in seismic interferometry.

Keywords: seismic interferometry, ambient noise, surface wave, velocity structure model, Chukyo area

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Estimation of Ground Structure By Microtremor Observation in Penang Island, Malaysia

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Recently, huge earthquakes have been frequently occured off the west coast of sumatra island. The shakes of these earthquakes were felt in many cities of Malay Peninsula and the government of Malaysia has the intended to establish seismic design code. In this research, the microtremor array observation has been carried out around the east coast of Penang island. As a fundamental investigation of the seismic microzonation, the dispersion curve of the phase velocity of the Rayleigh wave has been estimated by applying the SPAC method. Besides, the estimated velocity model was examined by using the H/V spectrum. Since the predominant period on the H/V spectrum was remarkable, the S wave velocity contrast of the subsurface ground and the engineering bedrock is can be analyzed and the depth of the subsurface ground is estimated to be dozens of meters.

Keywords: SPAC method, Microtremor observation, H/V spectrum, Malaysia

SSS33-P10 Room:Convention Hall Time:May 19 18:15-19:30

Determination of subsurface structure in the building damage area of Tohoku earthquake (March, 2011), Tsukuba City using

aiko kawamuki[1*], Tatsuya Noguchi[2], Takao Kagawa[2], Daichi Fukuda[2], Ikuo Cho[3], Shigeki Senna[4], Shinsuke Okada[5]

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Seismic intensity was recorded lower 6 at Tsukuba City, Ibaragi Prefecture when Tohoku earthquake (March, 2011) occurred.
A distribution map of tiled-roof damage ratio in the target area was made by Okada et. al. (2012).
Microtremor array observation at 20-sites and single-site 3-componets observation at 89-points were carried out in the area.
As the result, predominant periods of H/V at single observation points and subsurface structures at array sites were determined. Site amplifications were calculated using subsurface structure models at the array observation points. It is possible that site amplification factor was large and also resonance of house was occurred in the high area of damage ratio.
Therefore, it was considered that such seismic response is a cause of the high tiled-roof damage ratio.

Keywords: microtremor, Determination of subsurface structure, tiled-roof damage, Tsukuba City

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS33-P11 Room:Convention Hall Time:May 19 18:15-19:30

Determination of subsurface structure in Kurayoshi plain and North part of Daisen, using microtremor and gravity anomaly

Tatsuya Noguchi[1*], Daiki Adachi[1], Shun Okuda[1], Yoshihiro Ito[1], Takao Kagawa[1]

[1]Tottori Univ.

There were earthquake damages by the earthquake that occurred at the Middle West of Tottori in 1983, 2002 and the Western Tottori earthquake in 2000 in this study area. It is supposed that the damage influenced the subsurface structure. In northern part of daisen, many tourists gather on holidays. So it is important that the information of subsurface structures is obtained for prediction of ground motion in these areas. Microtremor and gravity surveys were carried out in the shore part of Kurayoshi plain and northern part of Daisen. S-wave velocity models are obtained at the array observation 9 sites and predominant period distribution at 3-components observation 140 sites newly. The gravity anomalies were obtained by gravity survey data at 122 sites newly.

Keywords: microtremor, gravity anomaly, subsurface structure, Kurayoshi plain, Northern part of Daisen

SSS33-P12 Room:Convention Hall Time:May 19 18:15-19:30

Estimation of ground structure using gravity survey method around Furukawa, Japan, where was severely damaged by the 201

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Estimation of ground structure using gravity survey method around Furukawa, Japan, where was severely damaged by the 2011 off the Pacific coast of Tohoku earthquake

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The 2011 off the Pacific coast of Tohoku earthquake caused vast damages to Japan, especially in the Northeastern part of country. Most of those damages came from the resulting Tsunami, some came from liquefaction, whereas only a few places were damaged by earthquake ground motions.

Furukawa in Osaki city is one of a few places, where was severely damaged by ground motions. Nevertheless, the level of damage to the structure within this town was totally different even the size of this town is not big, about 2km x 2km. In addition, there are 2 seismometers installed in this town, which are JMA-Furukawa and K-NET-MYG006 stations. Although distance between these 2 stations is about 1 kilometer, the velocity response spectrums of both seismometers were different about two times.

Therefore, investigation of ground structure is necessary. We carried out gravity survey in this town with the observation interval less than a few hundred meters because there was an estimation of depth to the engineering bedrock in this area is less than 50 meters. Moreover, we also carry out another observation using very dense sensors installed in this town to ensure the results of research. Within the area 2km x 2km, 34 sensors have been installed.

The Bouguer anomaly, as a result from gravity survey, has some significant variations in some places, which correspond to the most severely damaged places. Furthermore, residual anomaly as extracted from regional anomaly also states the similar fashion to both Bouguer anomaly and severe damaged places. Moreover, simulated 3-D map showing the altitude of basement, or engineering bedrock with the density of 2.4 g/cm3, presents the variations of the depth in 2km x 2km with the maximum different depth up to 67 meters.

These results from gravity survey are also corresponding to the latest result from very dense sensors project, which measured the arrival time of surface wave at every sensors from earthquake event on December 07, 2012 with epicenter off the Pacific coast.

Because the ground structure beneath this town is quite complicated and generate ground motions non-uniformly, so we will use receiver function analysis technique to supplement our study to better understand the characteristics of ground structure in this area.

Keywords: Furukawa, Osaki, Miyagi, 2011 Tohoku earthquake, gravity survey, ground structure, dense seismic array observation

Japan Geoscience Union Meeting 2013
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Relation between microtremor amplitudes and largest seismic oscillations observed at TRIES seismographic stations

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Seismographic stations of Tono Research Institute of Earthquake Science (TRIES) cover the Tono district in Gifu Prefecture since 1999. The station TRIES was the first station, and stations MIZUNAMI, INUYAMA, and others were established one after another. In order to investigate any relevancy between amplitudes of microseisms and maximum seismic spectral amplitudes, we started the data analysis of microtremors and seismographic data. By the discrete Fourier transform we calculated the spectral amplitudes and frequencies from the mainpart of the seismographs in the frequency range from 2.0 to 4.0 Hz. On the other hand we calculated the spectral amplitudes and frequencies of microtremors by the discrete Fourier transform at the intervals of 0.1Hz from 2.0 to 4.0Hz. We consider that the minimum amplitudes of microtremors in the small intervals of 0.1Hz represent the most quietest environment. Dividing the maximum amplitudes and minimum amplitudes at INUYAMA station by those at the referent station TRIES we get the information about the site effect at INUYAMA as normalized by the amplitudes at TRIES. The results indicate that the frequency of the maximm seismic amplitude corresponds to the frequency of rather small microtremor amplitudes. The comparisons of the maximum and minimum amplitudes on the site effects show such a clear tendency that the maximum spectral amplitude clearly relates to the small amplitudes of microtremors. This supports our presumption of the relevancy of the maximum seismic amplitudes to the minimum microtremor amplitudes.

Keywords: microtremor, seismic waves, discrete Fourier transform, ground soil, maximum amplitude, site effect

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Frequency dependence properties of seismic wave scattering and attenuation at the Kanto basin

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Introduction

It is well known that high-frequency seismic wavefield shows complicated propagation features caused by the seismic wave scattering due to small-scale heterogeneities along propagation path. In the shallow low-velocity layer, basin structures, the strength of scattering may be much stronger than it in deeper layers, i.e., crust and mantle.

In this study, to understand propagation characteristics of high-frequency seismic waves in shallow low-velocity basin structures, we estimate the scattering and intrinsic attenuation properties at Kanto basin by using coda envelope analysis.

Method

We used the waveform data recorded by K-NET/KiK-net and F-net seismic array in Kanto area, Japan, during earthquakes with Mw 4.5-5.5. We apply a set of band-pass filter with 1-2, 2-4, 4-8 and 8-16 Hz to three-component seismograms. Then we calculate mean square (MS) envelopes of sum of three-component seismograms for each frequency band. By the grid search analysis technique, observed MS envelopes were compared with calculated ME envelopes based on direct-simulation Monte Carole (DSMC) proposed by Yoshimoto (2000) in order to estimate scattering coefficient g_0 and intrinsic attenuation Q_I^{-1} in the medium.

To achieve precise estimation of parameters in the basin, first, we estimate the parameters in the crust and mantle using waveform data recorded at F-net. Then, using these parameters in the crust and mantle, we estimate scattering coefficient g_0 and intrinsic attenuation Q_I^{-1} in the Kanto basin using K-NET/KiK-net records.

Estimation results of scattering properties at Kanto basin

The values of estimated scattering coefficient and intrinsic attenuation in the crust are g_0 = 2.51x10-3, Q_I^{-1} = 5.74x10^{-3} for 1-2 Hz, g_0 = 2.93x10^{-3}, Q_I^{-1} = 3.35x10^{-3} for 2-4 Hz, g_0 = 3.98x10^{-3}, Q_I^{-1} = 2.28x10^{-3} for 4-8 Hz and g_0 = 5.41x10^{-3}, Q_I^{-1} = 1.33x10^{-3} for 8-16 Hz. Estimated scattering coefficients are smaller than these estimated by multi lapse-time window analysis (e.g., Fehler et al., 1992; Yoshimoto and Okada, 2009), while intrinsic attenuation values are comparable with them.

We estimated scattering coefficients and intrinsic attenuation in the Kanto basin derived from K-NET/KiK-net records. The values of estimated scattering coefficient and intrinsic attenuation in the basin are g_0 = 0.126, Q_I^{-1} = 6.71x10^{-3} for 1-2 Hz, g_0 = 0.0708, Q_I^{-1} = 5.96x10^{-3} for 2-4 Hz, g_0 = 0.126, Q_I^{-1} = 6.68x10^{-3} for 4-8 Hz and g_0 = 0.0891, Q_I^{-1} = 6.48x10^{-3} for 8-16 Hz. The estimated parameters for all frequency bands in the basin are larger than them in the crust. Estimated scattering coefficients in the basin are intermediate values between volcanic area and lithosphere (e.g., Sato et al., 2012). The values of total attenuation of S wave (Q_S^{-1} = Q_{Scat}^{-1}+Q_I^{-1}) are 2.68x10^{-2} for 1-2 Hz, 1.16x10^{-2} for 2-4 Hz, 1.17x10^{-2} for 4-8 Hz and 6.48x10^{-3} for 8-16 Hz. These results are good corresponding to estimation results by Kinoshita and Ohike (2002).

Acknowledgement

We acknowledge the National Research Institute for Earth Science and Disaster Prevention, Japan (NIED) for providing the K-NET/KiK-net and F-net waveform data.

Keywords: Seismic wave scattering, basin structure, intrinsic attenuation

SSS33-P15 Room:Convention Hall Time:May 19 18:15-19:30

Estimation of S-wave attenuation in the sedimentary layer beneath southern Kanto by using KiK-net borehole records

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1. Introduction

Seismic wave is amplified greatly at big cities in Japan that are generally located on thick sedimentary layer. In terms of seismic hazard estimation, it is important to evaluate amplification and attenuation characteristics of S-wave in the sedimentary layer. Because nowadays borehole seismic records are available all over Japan, it is possible to estimate Qs^{-1} values at many sites on the thick sedimentary layer. In this study, we estimate Qs^{-1} values by using KiK-net borehole seismograms obtained at three stations in southern Kanto operated by National Research Institute for Earth Science and Disaster Prevention (NIED).

2. Data

Seismograms obtained at Chiba (CHBH10), Yokohama (KNGH10), and Tokorozawa (SITH04) whose depths are 2000m are used. We analyze data recorded for periods from May, 2003 to February, 2011. Epicentral distances of analyzed events are within 150km and peak ground accelerations are less than 100cm/s^2. The numbers of analyzed events at the three stations are 89, 38, and 20, respectively. We apply a band-pass filter (1-10Hz). Transverse component of velocity waveforms is analyzed.

3. Method

Fukushima et al. (1992) estimated Qs^{-1} values by using incident S waves and surface reflected S waves on seismic records at a 732m-deep borehole at Chikura, southern Kanto region. In this study, we use a method slightly modified from theirs. First, we pick a start time t1[s], an end time t2[s] of an incident phase, and a lag time between the incident and the reflected phase on each observed waveform. Because the lag time is automatically determined for given t1 and t2, we only need to search for the optimal value of t2 with t1 fixed. The optimal value is determined so that correlation of these phases and amplitude of the reflected phase become highest. Finally, we calculate system functions from the incident and the reflected phases, and estimate Qs^{-1} values from the system functions.

4. Results

We fit a power-law model to the estimated Qs^{-1} values in the 1-5 Hz band. Qs^{-1} values at Chiba and Yokohama decrease with frequency with exponents of -0.76 and -0.50 and Qs^{-1} values at 1Hz of 0.020 and 0.032, respectively. On the other hand, Qs^{-1} values at Tokorozawa hardly show frequency dependence. Qs^{-1} values estimated for the stations are smaller than that for Chikura (Fukushima et al., 1992). We speculate that this difference is due to the depth dependence of Qs^{-1} values. Since the variation of Qs^{-1} values is as large as about $\pm$1 order so far, we need to investigate the cause. We plan to conduct similar analysis at many stations in order to understand relationships between Qs^{-1} values and other factors such as geology, S-wave velocity, and depth.

Acknowledgements: We are grateful to NIED for providing us with their digital seismograms of KiK-net.

Keywords: seismic wave attenuation, sedimentary layer

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SSS33-P16 Room:Convention Hall Time:May 19 18:15-19:30

Examination of source process for the 2011 off Miyagi earthquake of M 7.2 using strong-motion records

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The 7 April 2011 off Miyagi event of Mj 7.2 was a down-dip compression type earthquake in the Pacific slab, supported from the high dip angle in the moment tensor solution and the focal depth of 66 km. This is the largest event for the intra-slab earthquake occurring after the 2011 Tohoku great earthquake of Mw 9.0. The seismic intensity of 6 upper was recorded at Miyagi prefecture just above the source area, and the region of intensity 5 upper extended from southern Iwate to northern Fukushima prefecture. In this study detailed source rupture process is inferred by the inversion analysis using strong ground motion records in the source region. The source inversion algorithm adopted here is composed of the empirical Green's function method and the very fast simulated annealing developed by Shiba and Irikura (2005). In this inversion procedure we first estimate the spatial and temporal distributions of the slip and the rise time on the assumed fault plane from the relatively low-frequency ground motions. Then the effective stress and slip distributions are determined by using the result of the previous inversion analysis as a prior distribution of the new research with the waveforms in the higher frequency range. The fault plane model is assumed as the east-dipping plane with high dip angle based on the F-net moment tensor solution. For the empirical Green's function, the aftershock on 28 April of Mj 4.8 is employed and the sub-fault size is determined from the corner frequency of its source spectrum. Two horizontal velocity motions numerically integrated from the acceleration records at 21 KiK-net stations with one K-NET are provided for the inversion procedure. The source model derived from the slip and rise-time inversion shows rather simple slip distribution consist of one asperity located west of the hypocenter. The area of the asperity is 15 km long and 10 km wide, which is about 14 % of the whole rupture area. Rise time is relatively short of around 1 second, suggesting larger slip velocity and higher effective stress. Furthermore the source model obtained by the simultaneous inversion of the effective stress (peak slip velocity) and the slip indicates that the area of the high effective-stress is coincide well with the asperity, however the highest effective stress area is concentrated to the west end of the asperity, where the large slip ceases. The peak effective stress reaches about 120 MPa and the average on the asperity is 70 MPa, which is consistent with the stress drop on the strong motion generation area for the characterized source model of this event estimated with forward modeling analysis (Harada and Kamae, 2011; Somei et al., 2012).

Keywords: 2011 off Miyagi earthquake, intra-slab earthquake, source process, inversion analysis, strong motion record, effective stress

SSS33-P17 Room:Convention Hall Time:May 19 18:15-19:30

Estimation of the rupture process of the 2011 Fukushima-ken Hamadori earthquake using strong ground motion data

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1. Introduction

On April 11, 2011 in southeast Fukushima prefecture, the 2011 Fukushima-ken Hamadori earthquake (Mw6.6) occurred and it is thought to be triggered by the 2011 off the Pacific coast of Tohoku earthquake. Tsutsumi and Toda (2012) surveyed this area and found two nearly parallel surface ruptures, the Itozawa and Yunodake faults. The hypocenter determined by JMA is located west of the Itozawa fault so it is thought the Yunodake fault ruptured after the Itozawa fault did. There are few cases that surface ruptures are appeared by a crustal normal-fault-type earthquake in Japan. In this study, the source rupture process was estimated by using strong motion data with two fault models (the Itozawa and Yunodake faults). In addition, we compared the obtained slip distributions with the surface displacement distributions by Tsutsumi and Toda (2012).

2. Data and Method

Three components of time series data from nineteen strong motion stations of the K-NET, KiK-net and JMA are used. These original acceleration data are integrated into velocity, band-pass filtered with 0.1~1.0Hz and resampled at 10Hz. The dataset in the source inversion comprises 35s of the time series from 1s before the S-wave arrival. The Green's functions are calculated with the discrete wave number method (Bouchon,1981) and the reflection and transmission coefficient matrix method (Kennett and Kerry,1979) assuming a one-dimensional velocity structure model for each station which is extracted from the Japan three-dimensional integrated velocity structure model (Koketsu et al.,2012).

Two planar fault models (the Itozawa and Yunodake faults) are assumed. Their strike and dip angles are 156 deg.,73 deg. and 130 deg.,62 deg., respectively, in reference to Fukushima et al.(2013), the size of models is 22km$*$14km, 16km$*$14km in accordance with the aftershock distributions in a day after the mainshock. The rupture starting point of the Itozawa fault is shifted about 1.8km from the hypocenter by JMA. That of the Yunodake fault is assumed at northern end, middle, or southern end at the depth of about 12.3km.

The inversion method is the multiple time window linear source inversion (Hartzell and Heaton,1983). The rake angle variations are limited within the dip angle plus and minus 45 deg. The temporal moment-release history at each subfault is expressed by six smoothed-ramp functions which have the duration of 1.0s and each function is separated by 0.5s. The rupture front propagation velocity is 2.04km/s, which is 60% of the S-wave velocity at the rupture starting point of the Itozawa fault. The time difference between the Itozawa's and Yunodake's rupture starting time has five variations, 4.5, 5.0, 5.5, 6.0, 6.5s.

3. Inversion Result

The difference between observed and synthetic waveform is the smallest when the rupture starting point of the Yunodake fault is located northern end of fault model and the delay time is 4.5s. The total seismic moment was estimated to be $1.0*10^{19}$Nm(Mw6.6). On the Itozawa fault the large slip is found in the north of the rupture starting point in the shallow portion. On the Yunodake fault it is found in the north area of the fault model and south in the slightly deep portion. The obtained maximum slip is 1.6m on the Itozawa fault and 2.2m on the Yunodake fault. The slip distributions in the shallow portion of both faults almost correspond to observed surface displacement distributions.

The observed and synthetic waveform fit well when the rupture front propagation velocity and the time difference between two faults is small. Then we will examine slip distributions with more wide range of parameters. Furthermore it is necessary to consider the depth of rupture starting point of the Yunodake fault.

4. Acknowledgments

We thank the NIED, Japan and JMA for providing data.

Keywords: the 2011 Fukushima-ken Hamadori earthquake, the Itozawa fault, the Yunodake fault, sorce process, strong motion data

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Relation between stress drops and depths of strong motion generation areas based on previous broadband source models

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Miyake et al.(1999) showed that broadband strong motion records in the near fault regions for the 1997 Kagoshima-ken Hokusei-bu earthquake were simulated using strong motion generation areas (SMGAs) by the empirical Green's function method. After their pioneering work, the broadband source models composed of strong motion generation areas were estimated for many earthquakes by many researchers by the empirical Green's function method. On the other hand, Asano and Iwata (2011) studied on the relations between stress drops and depths of asperities for crustal earthquakes. Here asperities (Somerville et al., 1999) were estimated from long-period heterogeneous source models by waveform inversion method using strong motion records in the period range longer than about 1s. They derived the relation that the stress drop is large, so that asperity is deep. In this study we study on relations between stress drops and depths of strong motion generation areas based on previous broadband source models for crustal earthquakes in Japan.

Total 22 articles for 13 earthquakes with the moment magnitude Mw from 5.7 to 6.7 occurring to April, 2011 are used in this study. The numbers of the strike-slip, reverse, and normal faults are six, six, and one, respectively. We independently treat each source model for the same earthquakes, and so the total 25 source models are examined. We also independently treat each strong motion generation area.

The relations between stress drops stress [MPa] on SMGAs and the center depths h [km]are shown in the attached figure. The equations (1), (2), and (3) are derived from three data-set for strike-slip, reverse, and all-types faults, although the standard deviations of the regression relations are large.

stress=0.63h+7.88 (standard deviation=5.26) strike-slip (1)
stress=1.42h+8.54 (standard deviation=8.39) reverse (2)
stress=1.15h+7.98 (standard deviation=8.05) all (3)

The stress drops for reverse faults are larger than those for strike-slip faults at the same depth.

We also derive the relations between seismic moment M0 [dynecm] and total areas of SMGAs Sa [km^2] for strike-slip, reverse, and all-types faults as shown in equations (4), (5), and (6).

$Sa=4.57*10^{-16}M0^{2/3}$ (standard deviation=0.18) strike-slip (4)
$Sa=3.64*10^{-16}M0^{2/3}$ (standard deviation=0.09) reverse (5)
$Sa=4.02*10^{-16}M0^{2/3}$ (standard deviation=0.15) all (6)

Sa for strike-slip, reverse, and all-types faults are 0.9, 0.7, and 0.8 times of total area of asperities by Somerville et al.(1999). The result that total area of SMGAs are smaller than total area of asperities is interpreted by frequency-dependent source radiations (Satoh, 2010).

Short-period spectral level A which means the flat level of acceleration source spectrum (Dan et al., 2001) is represented by equation (7) based on the crack model (Brune, 1970).

$A=4pi(Sa/pi)^{0.5}stress\ Vs^{2}$ (7)

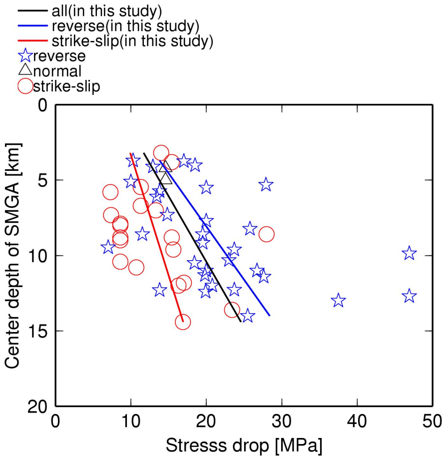
Here Vs is S-wave velocity of source and pi is circle ratio. We calculate A by substituting equation (1) to (6) for (7) assuming Vs=3.4km/s. The resultant A for all faults with depths of deeper than 7 km is larger than A derived from the M0-A relation by Dan et al.(2001). The A for strike-slip faults with depths of deeper than 10 km and reverse faults with depths of deeper than 5 km is larger than A by Dan et al.(2001).

As mentioned above, we derived the empirical relations that the stress drop is large, so that strong motion generation area is deep. In addition we showed that the stress drops for reverse faults were larger than those for strike-slip faults at the same depth. The relations between stress drops and depths would be useful for advancement of strong motion predictions for crustal earthquakes.

Acknowledgements:This study is a result of joint research "Study on improvement of evaluation method of earthquake ground motions taking into consideration the Pacific coast of Tohoku earthquake" by twelve electric power companies.

Keywords: strong motion generation area, stress drop, depth, empirical Green's function method, crustal earthquake

SSS33-P18 Room:Convention Hall Time:May 19 18:15-19:30



Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

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Determination of long- and short-period pulse sources of the 2011 Tohoku earthquake using the subduction zone structure

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The Tohoku earthquake on 11 March 2011 is a megathrust event on the subducting plate boundary. Several pulses can be seen in the strong motion records of this earthquake. It is important to determinate their sources using the subduction zone structure.

In our previous study, strong motion records by K-NET and KiK-net were used and integrated to long-period (10 ˜ 100 s) and short-period (0.01 ˜ 10 s) velocity waveforms using causal filtering, and we identified three main long- and short-period pulses, respectively. We located the pulse sources using arrival times of their initial motions. In our analysis, we used the 3-D velocity structure of the JIVSM model (Koketsu *et al*., 2008). The pulse sources were located by using a nonlinear, probabilistic earthquake location method called NonLinLoc (Lomax *et al*., 2000), in which a solution is represented by probabilistic density function and includes location uncertainties. The result showed that the long-period pulse sources were consistent with the results of the strong motion inversions by Koketsu *et al*. (2011) and Yokota *et al*. (2011), and that short-period pulse sources were consistent with strong motion generation areas by the empirical Green's function method (e.g., Asano and Iwata, 2012). Long- and short-period pulse sources were located to the up-dip and down-dip regions, respectively.

In this study, we picked the arrival times of the maximum amplitude of the second long-period pulse using a zero-phase filter, and located its source by the same method. Combined with the result of the initial motions, this study indicates that the slip related to the second long-period pulse occurred somewhat in the east of the epicenter about 56 s after from the origin time and expanded not seaward but landward. We plan to perform the same analysis of earthquakes of various magnitudes in the mainshock source region in order to check the validity of our analysis, and make detailed discussions.

Acknowledgement:
We would like to thank NIED (K-NET, KiK-net) for strong motion records and JMA for arrival time data of the JMA unified hypocenter catalog.

Keywords: 2011 Tohoku earthquake, strong ground motion, 3-D velocity structure, source process

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Relationship between asperity and surface earthquake faults for behavioral segments in a long active fault zone

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Introduction

Taking into account the characteristics of a behavioral segment in a long active fault zone can be the key to establishing a construction methodology of a source model for strong ground motion simulation for a variety of multi-segment rupture scenarios. In this research, we compile the source fault parameters and the geological fault parameters (e.g., surface displacements) for each segment of the source faults of inland crustal earthquakes. Based on the relationships among these extracted parameters, we examine a method to estimate inner fault parameters for each behavioral segment from these geological fault parameters.

Data and method

We target 7 earthquakes: 1979 Imperial Valley, 1992 Landers, 1995 Hyogo-ken Nanbu, 1999 Duzce, 1999 Hector Mine, 1999 Kocaeli, and 2002 Denali. For each segment of the source fault of these earthquakes, we utilize the source fault model, which was obtained by applying the waveform inversion technique in previous researches (e.g., Hartzell and Heaton, 1983; Wald and Heaton, 1994; Sekiguchi *et al.*, 2000; Birgoren *et al.*, 2004; Ji *et al.*, 2002; Sekiguchi and Iwata, 2002; Asano *et al.*, 2005), and extract the asperity area by following the procedure in Somerville *et al.* (1999). Then, we compile the outer fault parameters (segment length and segment width) and inner fault parameters (average slip on asperity and area of asperity) for each segment. We also obtain the geological fault parameters, such as the maximum value of coseismic surface displacements, and the recurrence interval. Here, we use the value obtained by multiplying the maximum value of surface displacements by the segment length, as a parameter value related to an shape of the distribution of surface displacements. In this presentation, we examine the segments with a segment length of less than 60 km and an aspect ratio (segment length/segment width) of less than 2.5.

Examination on the average slip on asperity and the area of asperity

The correlation coefficients between the average slip on asperity and, the segment length, the maximum value of surface displacements, and the recurrence interval are 0.49, 0.61, and 0.94, respectively. Here, the recurrence intervals for the segments ruptured in the 1992 Landers earthquake, 1995 Hyogo-ken Nanbu earthquake and the 1999 Hector Mine earthquake are used. The average slip on asperity is found to have a high correlation with the recurrence interval. The average slip on asperity also has a relatively high correlation with the maximum value of surface displacements. If we exclude two segments where the upper edge of asperity area reaches the ground surface and the relatively larger maximum value of surface displacements is observed, the correlation coefficients are improved (0.91). Moreover, the area of asperity correlates with the value obtained by multiplying the maximum value of surface displacements by the segment length (correlation coefficient: 0.62).

From our results, it is found that the maximum value of surface displacements correlates with not only the average slip on asperity, but also the area of asperity if we utilize the segment length together. This means that the maximum value of surface displacements is one of the useful geological fault parameters to estimate the parameters on asperity. We will examine the relationship between the inner fault parameters and both seismological and geological conditions near the source faults.

Acknowledgements

In this research, we use the source fault models compiled in the Finite Source Rupture Model Database (http://equake-rc.info/srcmod/). We sincerely thank Dr. Kimiyuki Asano for providing the information on the source model of 2002 Denali earthquake.

Keywords: long active fault zone, behavioral segment, asperity, surface earthquake fault

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(May 19-24 2013 at Makuhari, Chiba, Japan)

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Updating of source scaling relationships evaluated from the waveform inversion of recent inland crustal earthquakes

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Somerville et al.(1999) compiled slip models for fifteen inland crustal earthquakes (Mw5.7-7.2), and obtained empirical scaling relations for source parameters (total rupture area and asperity area). Irikura and Miyake (2001) proposed a recipe for predicting strong ground motion for future earthquakes based on mainly Somerville's empirical scaling relations.

After 1995 Hyogo-ken Naubu earthquake, a lot of strong ground motion stations (K-NET, KiK-net) have been installed in Japan by NIED (National Research Institute for Earth Science and Disaster Prevention). A large amount of the waveform inversion analyses have been done in recent years for estimating rupture processes using strong ground motion data.

Using the waveform inversion results of resent fifteen crustal earthquakes (Mw5.6-6.9), which happened after the 1995 Hyogo-ken Naubu earthquake, we try to revise the empirical scaling relationships between seismic moment and entire rupture area and between seismic moment and asperity area. According to the criterion of Somerville et al.(1999), we extracted the entire rupture area (S) and the asperity area (Sa) from inverted heterogeneous slip distribution. The combined area of asperities over the entire rupture area is about 0.17 in average for fifteen earthquakes. The averaged ratio (Sa/S) of the combined area of asperities to the entire rupture area is smaller than Somerville's result (0.22). The averaged ratio (Sa/S) varies dependent on fault type (strike slip, reverse slip, and normal slip) as follows.

Strike slip type (seven earthquakes): Sa/S = 0.16
Reverse slip type (seven earthquakes): Sa/S = 0.16
Normal slip type (one earthquakes): Sa/S = 0.22

It should be examined whether the asperity areas (Sa) obtained above are effective for strong motion prediction, comparing them with strong motion generation areas from simulation using the empirical or stochastic Green's function method.

Acknowledgments: We thank Dr. Asano(DPRI), Associate professor Sekiguchi (DPRI), Professor Iwata, Dr. Horikawa(AIST), Dr. Hikima(TEPCO), Dr. Suzuki(NIED), and Dr. Aoi(NIED) for providing waveform inversion results. We also used waveform inversion results from JMA.

Keywords: strong ground motion, a recipe for predicting strong ground motion, empirical scaling relations, waveform inversion

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Examinations toward establishing procedure of evaluating fault parameters for predicting strong motions from intra-slab

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For precise prediction of strong motions from intra-slab earthquakes, it is necessary to establish a new procedure of evaluating fault parameters based on the characteristics of intra-slab earthquakes. Although such studies have been conducted by Sasatani et al. (2006) and Dan et al. (2006), procedures of evaluating fault parameters that have been proposed have not been fully verified by reproduction of the actual earthquake records. Then, in this study, we simulated the ground motion of the intra-slab earthquake that occurred off the coast of Miyagi Prefecture on April 7, 2011 and we pointed out the problem of existing procedures of evaluating fault parameters and suggested the ideas to overcome the problem.

In the case of the intra-slab earthquake of April 7, 2011, there was a possibility that the result of evaluation of strong ground motion using the equation of short period spectral level proposed by Sasatani et al. (2006) or Dan et al. (2006) became too small. But we found that the fault models could not be set due to negative slip amounts on the background area by only increasing the short period spectral level according to the detailed knowledge of this earthquake obtained by Harada and Kamae(2011). For this problem, we developed three new fault models using a method to reduce the area of the asperities while increasing the short period spectral level and using a crack model.

We set five fault models of the intra-slab earthquake off the coast of Miyagi Prefecture on April 7, 2011, which are models just based on the relationships of intra-slab fault parameters by Sasatani et al. (2006), another one by Dan et al. (2006), and newly proposed three fault models. By using these five fault models, we evaluated strong ground motions at several KiK-net stations by the empirical Green's function method. As a result, ground motion evaluation results using Sasatani et al. (2006) and Dan et al. (2006) are smaller than the actual records especially at the observation stations near the epicenter. On the other hand, ground motion evaluation results using the newly proposed three fault models showed better agreements with the actual records.

Keywords: Intra-slab earthquakes, Strong motion prediction, Fault model

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(May 19-24 2013 at Makuhari, Chiba, Japan)

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Source Process Analysis of the 1995 Kobe Earthquake Using 3-D Velocity Structures

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The Kobe (Hyogo-ken Nanbu) earthquake with a JMA magnitude of 7.3, which occurred on 17 January 1995 near the Akashi Strait located in the southern part of Hyogo Prefecture, caused great disaster. The notable feature of this earthquake is violent ground motions with a JMA intensity of 7 occurred in a narrow zone, called ”damage belt”. Previous studies (e.g., Kawase, 1996; Furumura and Koketsu, 1998) have shown that their occurrence is attributed to the 3-D velocity structure in this zone. This indicates not only that a 3-D velocity structure significantly affects strong ground motions, but also that we should consider its effects in precisely determining the rupture process of this earthquake. However, the previous studies of source process analyses only used 1-D or half-space velocity structure models.

In this study, we calculated 3-D Green’s functions for the strong-motion and geodetic stations located in the Osaka basin using a 3-D velocity structure model. Then, we performed a joint inversion of strong motion data, teleseismic body waves and static displacements for the source model of the earthquake. Before performing the inversion, we validated the 3-D velocity structure model and refined it using the strong motion data of aftershocks.

We compared our source model to that of Yoshida *et al.* (1996), which is one of the previous studies. The seismic moment and largest slip in our source model are slightly larger than those of Yoshida *et al.* (1996). Distinctive differences are seen in between our source model and that of Yoshida *et al.* (1996): a new large-slip zone beneath the city of Kobe and larger slips in the shallow part along the Nojima fault. These differences suggest that our source model is more consistent with the violent ground motions in the ”damage belt” and the surface rupture of the Nojima fault. We also confirmed that our source model realized better fit to the strong motion observations.

Keywords: Source process, Joint inversion, 3-D Green’s function, Velocity structure

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Main shock-aftershock interval effect on the liquefaction damage in Tohoku Region Pacific Coast Earthquake

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During the Tohoku Region Pacific Coast Earthquake, extensive liquefaction damages were observed over a wide range of reclaimed coastal land. The following two characteristics have been pointed out: (1) Large liquefaction damages occurred even under small ground acceleration. (2) Intermediate soils with large fine fraction content that have been considered to be hard to liquefy also exhibited extensive liquefaction. While long duration of the seismic motion may be one of the main reasons for them, the authors previously focused on the stratum organization. That is, soft alluvial clay located directly under the alluvial sand on the inland side is thin, where liquefaction damage is relatively small. The thickness of this clay layer increases as it approaches to the coastal side, where liquefaction damage becomes severe. Based on the 1D elasto-plastic seismic response analysis, the authors indicated that a thick soft clay layer below the liquefied layer can amplify seismic waves over a range of longer periods, and the resulting large plastic strain may cause severe liquefaction damage even in clayey sand that normally resists liquefaction.

The third characteristic will be (3) large aftershock generated only 29 minutes after the main shock expanded the liquefaction damage, considerably. In this study, authors focused on the influence of main shock-aftershock interval to the liquefaction damage. Before the elasto-plastic seismic response analysis, elasto-plastic soil properties were precisely identified by the various soil tests in laboratory using undisturbed soil samples obtained through boring exploration in the Urayasu city, details for which will be delivered later.

The difference of the thickness of clay layer affects greatly on the liquefaction damage as shown in Fig. 1(a). Fig. 1(b) indicates the time-excess pore water pressure ratio relationships during the aftershock that occurred 29 minutes after the main shock. D foundation with a very thin clay layer does not exhibit any liquefaction during both main shock and aftershock. To the contrary A and B foundations with a thicker clay layer, liquefaction was clearly observed both during the main shock and during the aftershock. The C foundation exhibited interesting behavior. The C foundation is on the relatively thin clay layer, and this foundation does not exhibit liquefaction during main shock. However, 29 minutes after the main shock the foundation reaches liquefied state during aftershock (Fig.1 (b)). This is, of course because 29 minutes is not long enough for the dissipation of excess pore water pressure even for the sand which is covered with reclaimed clayey soil layer of small permeability. Suppose that the aftershock occurred one day after the main shock. Fig. 1(c) shows the time-excess pore water pressure ratio relationships during the aftershock. No foundations from A to D exhibit any liquefaction during the aftershock. One day interval will be long enough for the excess pore pressure dissipation through the top clayey sand layer. Short interval between main shock and aftershock may have enlarged liquefaction damage in Tohoku Region Pacific Coast Earthquake.

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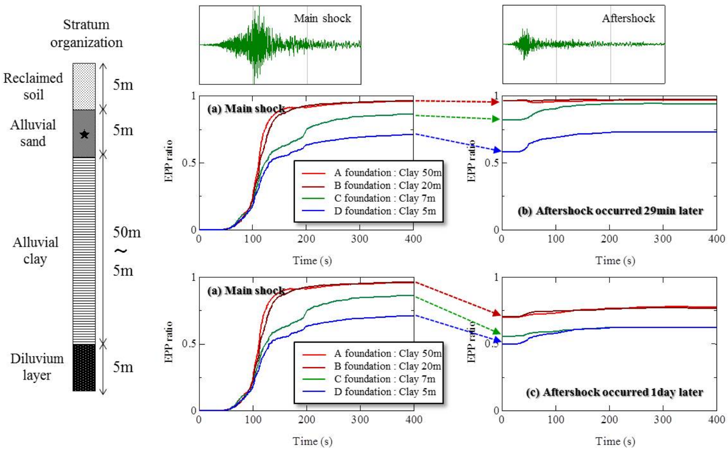
Keywords: Liquefaction, Clay layer thickness, Main shock ? aftershock interval, Elasto-plastic seismic response analysis

SSS33-P24 Room:Convention Hall Time:May 19 18:15-19:30



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Effect of the non-linearity of the ground in synthetic ground motion by using Empirical Green's Function

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[1]Tokyo Institute of Technology

In seismic hazard in an engineering problem, it is required to consider the ground motion in a period band of about 10 seconds from 0.1 seconds. Strong ground motion in a period range of less than one second are controlled by generation region called [asperity] on a fault plane. The short-period component, is also strongly influenced by characteristics of the propagation path effect. In order to obtain such effects theoretically it is required a huge amount of calculation and data for underground structure. It is also necessary for more accurate evaluation method of ground motion.

In this, we calculate synthesis ground motion of main shocks for past events by using the empirical Green's function method, and to assess the effects of the non-linearity of soil from the difference between the observed and synthesis waveforms.

We compared the observed waveforms and synthetic waveforms at the observation point K-net during five crustal earthquakes occurred in Japan, using the source model obtained by the inversion in the past. We used characterized source models that has been obtained in previous studies, first, I was examined how much the non-linearity effects of soil are included at the observation point by comparing the observed and synthetic waveforms. When PGAs are more than 200gal, PGVs are greater than or equal to 10kine, the synthetic waveforms tend to be significantly different from the observation waveforms. In order to evaluate quantitatively the nonlinearity of the soil of each observation point, using (which was summed in the frequency domain for each ratio of H / V spectrum at the aftershocks and the main shock) DNL method, we examined the relationship DNL and the PGA. Then, for the PGAs above 200 gal, the DNL has become equal to or greater than 6, and the DNL for PGA of 200gal is about 4. We have found that DNL is one of good parameters to evaluate the nonlinearity of the soil. This is also consistent with the results by Noguchi (2009). Next, we evaluated the effect on PGV and PGA ratios (synthesis/observations) with the difference condition of subsurface structure. We used the difference of each Vs20 which is the S-wave velocity average of up to 20m depth as parameters for the soil condition. In spite of the differences in the Vs20, the relationship between the Vs20 and PGA or PGV ratios is not so clear. One of the reasons for this is that the used characterized source model only asperity source model, was not sufficiently tuned model for all sites.

We try to assess the effects of nonlinear amplification by quantitatively evaluating the difference between the synthesized waveform and the observed waveform and adding to the result of empirical Green's function method. However, the PGA and PGV from observed waveform cannot good parameters for this evaluation, because of including high frequency pulses Different evaluation criteria, such as seismic intensity and spectral integration value will be examined.

We thank National Research Institute for Earth Science and Disaster Prevention for the seismograms of the stations in the K-net and KiK-net.

Keywords: Empirical Green's Function, non-linearity of soil, DNL, strong motion

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS33-P26 Room:Convention Hall Time:May 19 18:15-19:30

Rough and rapid estimation of rupture area for gigantic earthquakes from seismic intensity distribution

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We are developing some rapid estimation techniques for rupture area roughly. Yokota and Kaida (2011) proposed a method for estimating rupture area for a big earthquake($Mw > 8.0$) from seismic intensity distribution. In their method, they estimate rupture area on the plate boundary with relationship between the shortest distance from source area and Mw. It is difficult to estimate rupture area especially near trench (far area from land) with this method. And it takes 10min after earthquake occurrence to analyze the source area, because small seismic intensity data are observed late due to travel delay.

In this study, we use only seismic intensity data of large values to estimate rupture area. By using only large intensities, we can analyze 3min after earthquake occurrence in the case of 2011 Tohoku-oki earthquake. Since large seismic intensities are observed at a short epicentral distance, we can estimate the outer rim of the source area.

We will report results for other large earthquakes.

Keywords: Rapid estimation of rupture area, seismic intensity distribution

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The Surface Distributions of the Durations of the Low Frequency Seismic Waves

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If large earthquakes occured, the 2011 off the Pacific coast of Tohoku Earthquake for instance, low frequency seismic waves with 2 second or longer periods were observed. These sometimes cause damages for high-rise buildings and other large structures. However JMA has no method to announce observed data about low frequency seismic waves. Therefore JMA has considered how to announce them from 2011 and will establish new information.

As for strong ground motion, seismic intensities are used generally. In addition, specialists use PGA and PGV. On the other hand, maximum amplitudes of velocity about various frequencies are important to grasp low frequency waves. Furthermore those time series are also important because those damping rate are smaller than those of strong motion.

In Japan, seismic intensities can be grasped in detail by about 4300 intensity-meters. However there are only about 1500 stations which can observe low frequency waves: that is K-NET, Kik-net, F-net of NIED and JMA strong motion observation network. We must estimate low frequency motion on each place by those limited data. Muto and Katsumata (2012) proposed spatial interpolation of maximum velocities using natural periods which calculated from the subsurface velocity structures. We considered the relation between natural periods of subsurface structures and time series of ground motions in this study.

We investigated 2 parameter: (1) the periods from the P-wave arriving times to the peak amplitudes appearance ones, and (2) the durations that large amplitude waves continued. On the second one, we can give some definiations. In this study, we calculated durations of time series of velocity responce using a method by Izutani and Hirasawa (1987). It was ascertained that the ratios of the durations of S-wave calculated by 0.1-0.5 Hz velocity responces to those of P-wave calculated by 5Hz them were fixed generally regardless of locations. On the other hand, We found that there were correlations between durations whose amplitudes were above certain thresholds and subsurface structures. Using those two knowledges, it may be able to forecast the durations of low frequency seismic waves at any point by the durations of high frequency ones solved by actual records observed at nearby stations.

Acknowledgements.
K-NET, KiK-net and F-net data of NIED were used in this study.

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Keywords: low frequency seismic wave, ground motion duration, deep subsurface structure

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Ultra high density questionnaire seismic intensity survey and the shallow S-wave velocity structures

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To clarify the vibration characteristics in central Maesawa Town of Oshu City, Iwate Prefecture, the dense survey of seismic intensity was done using questionnaires for the 2011 off the Pacific coast of Tohoku Earthquake and the aftershock occurred at April 7, 2011. This earthquake was the aftershock of the 2011 off the Pacific coast of Tohoku Earthquake. JMA reported that the seismic intensities at the Maesawa Town of Oshu City were 6 weak for the main shock and same for the aftershock. The questionnaire revised by Ohta et al.(1998) was used for calculating seismic intensity. The seismic intensities estimated from questionnaires were averaged for 250 m square meshes to clarify the distribution of seismic intensity in the central area of Maesawa Town. To avoid differences among individuals for questionnaire survey, the effective mesh where the number of the questionnaire was more than three was used for analysis. The mesh that seismic intensity was 6 strong were found for theresult of the aftershock. The results shows that the seismic intensity was large at the area where houses were damaged. Microtremor observations with a single and/or array sencers were also carried out in this area. Results of microtremor H/V shows clear peaks in the damaged area, namely Gojunin-machi area, but do not in other area. Estimated shallow S wave velocities from microtremor array survey are small, e.g. about 100 m/s in the damaged area but not in other area.

Keywords: the 2011 off the Pacific coast of Tohoku Earthquake, aftershock at April 7 in 2011, Questionnaire Seismic Intensity Survey, earthquake damege, Maesawa Town, Oshu City, Iwate Prefecture, microtremor array survey

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Relationship between liquefaction occurrence ratio and strong ground motion duration

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A report of research that the length of strong ground motion duration time including aftershock of the 2011 Tohoku-oki earthquake enlarged the damage range and scale of liquefaction occurs.

In this research, it aims at examination of the influence of the duration time of the strong ground motion of the 2011 Tohoku-oki earthquake about liquefaction occurrence rate.

First, "the real-time seismic intensity" by Kunugi et al(2008) and instrumental seismic intensity were calculated from strong ground motion waveform record.

Next, the relation with strong ground motion duration time was considered using the technique of calculating a liquefaction occurrence rate of Matsuoka et al(2011).

As a result, the liquefaction occurrence rate of the 2011 Tohoku-oki earthquake are much larger than those of past earthquakes caused liquefaction.

Moreover, it turned out that the size of strong motion duration time also affects a liquefaction occurrence rate of incidence.

Keywords: Liquefaction, Liquefaction occurrence ratio, Strong ground motion duration, Realtime intensity, Geomorphologic classification

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On-site experiment of seismic monitoring network by utilization inside sensors of mobile terminal

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Mobile terminal devices have a small, lightweight, and cheap accerelation sensor called MEMS, and also have a bettery and wireless communication adaptor inside it. If we use such MEMS sensor for observation of earthquake and then upload to cloud computing system, we would know detailed information of shaking. And If we share information observed by MEMS sensor using the cloud computing system, we could raise awareness about disaster prevention. For example, Yoshida et al.(2011) developed an experimental earthquake observation system using the iPhone/iPad/iPod touch named "i-Jishin", and released in August, 2010.

Furthermore Naito et al. (2011) installed "i-Jishin" on the base and observed in parallel with K-NET02 seismometer. They compared same seismic waves, then concluded as regarding JMA intensity, over 3 it is within the margin of 0.1, but up to 2 it becomes overestimate.

In this research, we report about the performance of MEMS acceleration sensors and on-site experiment of seismic monitoring network by utilization inside sensors of mobile terminal.

In order to examine the possibility of application about strong motion observation of the building using "i-Jishin", we installed it on two different floors in the low-rise 5 RC buildings, and started monitoring from January 2012. After installation, we were able to get a large number of earthquake records corresponding up to an intensity 4. By analyzing these data, one building showed significantly high velosity response value. This building was significantly damaged in the non-sutructual component after the Tohoku-Pacific Ocean Earthquake. After that, we tried the microtremor observation using JU-310(Hakusan Corp.), we found the largest gain compared to others in this building looking at the H / V spectral ratio, and it was consistent with the result as previously mentioned.

In addition, for the purpose extracting social issues, we installed "i-Jishin" on the floors of more than 30 different buildings which have different types of structure and network environment around the city of Nagaoka, Niigata Prefecture and Fujisawa, Kanagawa Prefecture since January 2012.(Azuma et.al, 2012) In that case, the staff of NPO installed terminals and they are considered favorable, so well understood about the effect of sensing. However, many problem was found such as, diversity of networking enviroment, no easily understandable benefits of the installation, requirement to ensure the stability of the measurement, and the human resources for maintenance.

To solve these promblems, we will develop a more reliable and accurate system or a sytem that is easily understanble for general person. Besides we are going to enhance the cooperation with "i-Bidou" which is the system of the cloud type microtremor observation system(Senna et al.2012). We will keep developing the system to visualize the harzard information of regional soil and building conditions, and keep performing experiments of the sensor network system so that everyone can measure and share information of the buildings.

Keywords: MEMS, Cloud, Sensor Network, On-site experiment

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Attenuation measurements by laboratory tests using rock core samples for earthquake ground-motion estimation

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An applicability of attenuation measurements by laboratory tests using rock core samples (5 cm-diameter and 10 cm-long) is described. The pulse rise-time technique [Gladwin and Stacey,1974] and the spectral ratio technique [Toksoz et al, 1978] were applied to measure an attenuation of four granite core samples by ultrasonic wave measurements using S-wave transducer of 100 kHz. As a result, the damping factors ranged from 0.009 to 0.014 (Qs=37~54) were obtained from the pulse rise-time technique. Additionally, from the spectral ratio technique, the damping factors ranged from 0.009 to 0.014 (Qs=37~54) were obtained by using aluminum with Qs=150000 [Zamanek and Rundnik, 1961] as a reference sample. These results indicate that almost equal damping factors are estimated by two different techniques used ultrasonic wave measurements. Further, the cyclic uni-axial compression tests using cyclic loading wave of 0.1 Hz were also performed to get stress-strain curves with ten stress-levels for same samples used in ultrasonic wave measurements. From the stress-strain curves, we found that the curves with the strain levels lower than about 2.x10^{-5} were difficult to provide reliable damping factors because of an unstable and distorted shape of hysteresis loops. Meanwhile, the damping factors with the four strain levels ranged from 2.6x10^{-5} to 2x10^{-4} were obtained from the stress-strain curves and showed strain-dependent characteristics. The damping factors of minimum strain level of 2.6x10^{-5} were obtained from 0.008 to 0.01 (Qs=50~63). From the comparison with the results from ultrasonic wave measurements, we showed that almost the same damping factors of small-strain level were estimated by the two different methods.

Keywords: rock core sample, attenuation measurement, ultrasonic wave measurement, cyclic uni-axial compression test, near surface rock, earthquake ground-motion estimation