Special Project for Reducing Vulnerability for Urban Mega Earthquake Disasters: Hazard and Risk in metropolitan Tokyo

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We have implemented a dense seismic network, MeSO-net (Metropolitan Seismic Observation network), since 2007 in the greater Tokyo urban region under the Special Project for Earthquake Disaster Mitigation in Tokyo Metropolitan Area (FY2007-FY2011) and Special Project for Reducing Vulnerability for Urban Mega Earthquake Disasters (FY2012-FY2016; Hirata et al., 2009). So far we have acquired more than 150TB continuous seismic data form MeSO-net, which consists of about 300 seismic stations. Using the MeSO-net data, we obtained clear P- and S- wave velocity tomograms (Nakagawa et al., 2010) and Qp, Qs tomograms (Panayotopoulos et al., 2014), which show a clear image of the Philippine Sea Plate (PSP) and the Pacific Plate (PAP). Our results showed that the depth to the top of PSP beneath the northern part of Tokyo bay is roughly 20 to 30 km, which is approximately 10 km shallower than previous estimates based on distribution of seismicity (Ishida, 1992).

We are developing a method to estimate the seismic intensity distribution by an earthquake of arbitrary location and magnitude. This will enable us to correlate it to historically recorded seismic intensity distribution and estimate the hypocenter and magnitude of past major earthquakes in the Kanto region.

In addition, the change of seismicity rate after the 2011 Tohoku-oki earthquake suggests a change of the stressing rate in the greater Tokyo area. Quantitative analysis of MeSO-net data shows a significant increase of the rate of earthquakes that have a fault orientation favorable to increasing Coulomb stress after the Tohoku-oki event.

Keywords: Metropolitan Tokyo, Seismic Hazard, Philippine Sea Plate

Development of "Disaster Management Literacy Hub" (DMLH) to Enhance Disaster Management Literacy

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The concept we propose for a disaster management literacy hub (DMLH) involves systemizing and generalizing disaster management literacy (DML) and discussing how to design such a DMLH where the general public and disaster responders share materials on DML.
In the early 21st century, measures against large-scale earthquakes should essentially include both hardware disaster mitigation measures like the construction of appropriate structures and software measures like disaster preparedness among people and organizations such as the general public, disaster responders and related organizations. We define knowledge about disaster response management and competency as DML.
We proposed that DML consist of three elements: knowledge for learning about disaster management and mitigation, skills required for effective disaster response, and basic competency and attitudes for coping with disasters. For conceptual DMLH design based on the Instructional Design (ID), we propose three types of learning:
1) The general public and disaster responders learn audiovisually using training videos and materials and review tests on learn from videos.
2) People who want to provide education and training at schools or in regions or municipalities with school teacher guidance/teaching plans learn how to do so.
3) People learn DML by posting or searching for (collecting and arranging) materials.

Keywords: disaster management literacy, Instructional Design (ID), competencies for disaster responses, education and training

Development and Utilization of Urban Resilience Geoportal Online

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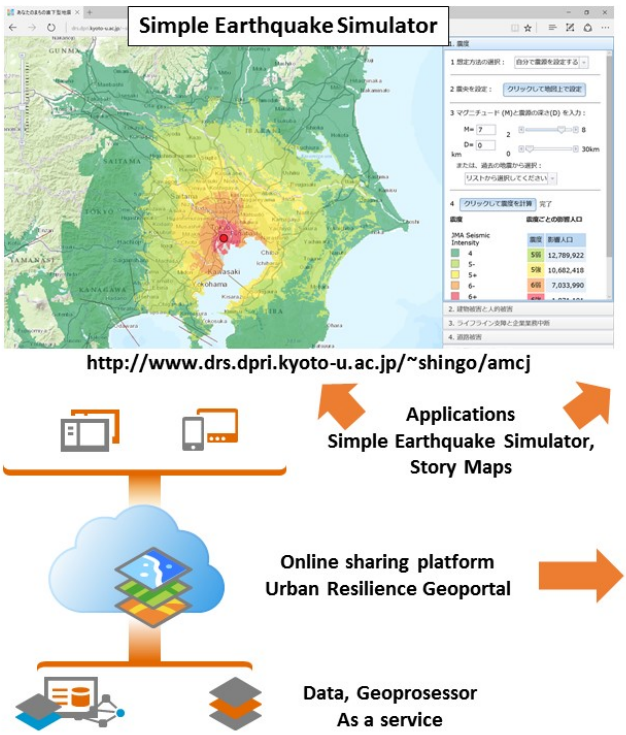
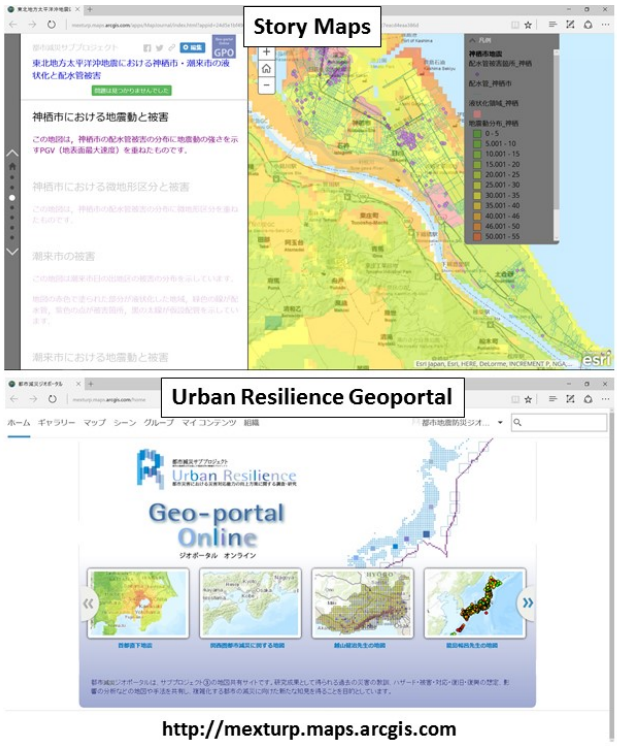
In the Subproject to develop resilient society improving disaster management competence of MEXT Special Project for Reducing Vulnerability for Urban Mega Earthquake Disasters, we are developing web-based disaster-related geospatial contents sharing system called “Urban Resilience Geoportal Online” to integrate the achievement of multidisciplinary researches on the processes and impacts of mega-disaster.
The mega-disasters predicted in Japan, such as Tokyo Metropolitan Earthquake or NankaiTrough Earthquake Tsunami, bring huge amount of damage and loss in various sectors and various regions, and the scenarios of damage occurrence and loss propagation are very complex. Hence, in order to quantify each problem’s importance to create disaster reduction strategies, it is very important to share and integrate data and findings across many disciplines and regions. In order to share various contents and utilizing them in various organization, we considered DIKW(Data, Information, Knowledge and Wisdom) model which is chain of thinking used in knowledge management.
Firstly, we developed community based GIS(Geographic Information System) data sharing portal site utilizing ESRI ArcGIS Online for Organization in order to share contents at data level. Researchers as community members who participate in this subproject upload their data to this portal site in the form of web map service layer which is easily mashed up with other researcher’s layer on ArcGIS Online. These uploaded layers are registered in catalog system and users can search, view, mash up them on demand in catalog system or in web map viewer easily. More than 500 layers including base data, hazard data, vulnerability data and the damage and response data of past disasters are gathered in the geoportal.
Secondly, in order to share contents at information level, we developed the method to share researchers’ data analysis model or impact estimation model. In earthquake disasters, many kind of damage and impacts occur in complex processes and many kind of person or organizations should prepare based on the estimation which is consisted of many data and models. The new method to share various models to analyze or estimate situation uses web GIS services. Data required in models are provided by data services. Geoprocessing service processes geospatial calculation based on a model using data from data service and create result as result service.
In order to give people or organization personalized estimation information, we made the simple earthquake disaster estimation application that everyone can estimate that with web browser combining these shared data and geoprocessing services. From the development procedures, making and sharing components as services enables estimation of complex disaster process because they can be combined flexibly according to needs, and this can promote collaboration of multidisciplinary researchers faster.
Thirdly, in order to share contents at knowledge level, we utilized Story Maps. Map or layer can’t by itself transfer knowledge. People often can’t understand what they should read from a map. People often misunderstand what the creator of the map intended to explain, or should know the story lying behind the map. So we combined story and map with ESRI Story Maps web application template. Story Map can display a series of maps according to a story along with the text which explain what displayed map is, what the map aims and what users should read from the map. Several research achievements suitable for geographic expression were shared their findings as knowledge with Story Maps. We think this method can contribute to the risk communication between specialists

and non-specialists.
Lastly, in order to share contents at wisdom level, we are now developing response management simulator in which coordinators of disaster response in organizations can train their skills of decision making under various situations.

Keywords: WebGIS, Simulator, Story Maps





A simulation of drainage of influent water caused by tsunami at Tokushima.

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It is said that great earthquake will occur in the near future at the Nankai subduction zone. The tsunami of this earthquake will damage Tokushima. The effect of this tsunami has been predicted by using numerical simulations, and measures are being taken. But there are few discussions about influent water. In Tokushima, there are some places that lands are low and are surrounded by levees, where the influent water should become obstacles to rehabilitation. So we attempted to simulate it in this study.
Simulation procedure is as follows. First, we simulated tsunami caused by an earthquake with the non-linear long wave theory to target areas. The tsunami can flow into the target areas by overflow formula (Honma, 1940) when the wave becomes bigger than the levee. Water movements inside the levee are simulated as 2D unsteady shallow water flow. It is also modeled open channels, sewer pipelines, drainage pumps to simulate drainability. We used AFREL (Application of Flood Risk EvaLuation) software to simulate inland flow.
In a simulation using case 3 of Cabinet Office earthquake source models as input, the first wave reached at Okinosu area, Tokushima, about 40 minutes after the earthquake. After about 42 hours, 90.6% of the maximum wetted surface area were drained, but the others were not drained because of sunken place. We can’t drain these water any more in this calculation. In the next calculation, we stopped 3 pumps which drainage capacity are better than the others (there are 12 pumps in this area). In this case, only 55.2% of the maximum wetted surface area are drained at 72 hours after the earthquake. Furthermore, these pumps are made to drain water caused by rain, so these may not work for seawater or during long-time blackouts. It may be needed to take some additional measures for the influent water caused by tsunami.

Keywords: drainage, tsunami

Development of User-Interactive Application Supporting for Detection of Tsunami Evacuation Route with Land Features and Hazard Information

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1. Background and Objectives

Based on lessons learned from 2011 East Japan Earthquake, Cabinet office of Japan has promoted local governments and communities to develop “Community Disaster Management Plan”. Local governments started to develop the plan in the view of the circumstances in their regional characteristics. Niigata city also organized the workshops in order to develop it against tsunami disaster with residents. Only a few residents participated in this workshops and they build their capacity due to workshop schedule and largeness of place. Other residents did not have opportunities to discuss about disaster prevention. Against this issue, we decided to develop an application supporting for individual disaster management plan in analyzing hazard risks and land features around their habitation area.

2. Clarification of Work-flow for Developing Evacuation Plan at Tsunami

We conducted preliminary survey in these workshops in order to design the work-flow for users to develop their own disaster management plan at tsunami. Especially, in this research, we narrowed down a target to evacuation plan because evacuation is most important behavior to save their lives. Through the workshops in Niigata city, we found the processes of developing evacuation plan was consisted of 5 steps. 1) Introduce fear of tsunami disaster and countermeasure at tsunami disaster, 2) Survey the evacuation route from each participant’s house to public tsunami evacuation center, 3) Discuss potential risks behind participants’ community, 4) Design strategic plan for their community and to discover potential evacuation center such as non-pubic high-rise buildings, 5) Report and share the result of their discussion. Furthermore, it is a unique feature in these workshops to set 2 evacuation goal. First goal is near-by their habitation place and it is built in high elevation area. Second one is far from the impacted area by tsunami and it is located in higher elevation area than first one. This was followed by lessons learned from Kamaishi Evacuation Story at East Japan Earthquake in 2011.

3. Development of Prototype of User-Interactive Application

We developed a prototype of application based on the system-design described above. In this application users can detect rational evacuation route considering hazard risks and land features. Because we supposed that users cannot detect it at one time, we decided to develop the application as web-based and user-interactive application. This means our developed application should respond the result of analyzing the risks around their detected evacuation route in conjunction with the modification of users’ evacuation route. Finally we developed the prototype of application following 7 users’ steps: 1) Set start point for evacuation, 2) Set first evacuation goal, 3) Set second evacuation goal, 4) Search shortest evacuation route, 5) Review change of elevation on evacuation route, 6) Judge hazard risks and land feature on evacuation route, 7) Download evacuation route dataset as a local file. From step1 to step5, we utilized Google Map API for searching specific place name or street address, and for evaluating transition of elevation on the detected evacuation route. In step7, users can download the detected evacuation route as GPX file for reviewing it on GIS software they have later.

4. Discussion

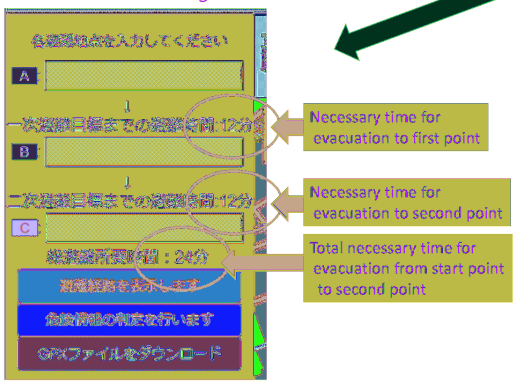
We implemented the application and published it for 10 days in order to examine its effect. Through this examination, we gained 1,960 users' logs. Deciphering those logs, only 223 of rest 851 users detected their rational evacuation route considering hazard risks and land features around the detected evacuation route. We found that the complicated user-interface and system transaction caused this result. Against these issues, we are planning to modify it with higher user-friend interface and to build a story for developing their evacuation route in it.

Keywords: Micromedia Service, Tsunami Disaster, Evacuation Route, Urban Resilience

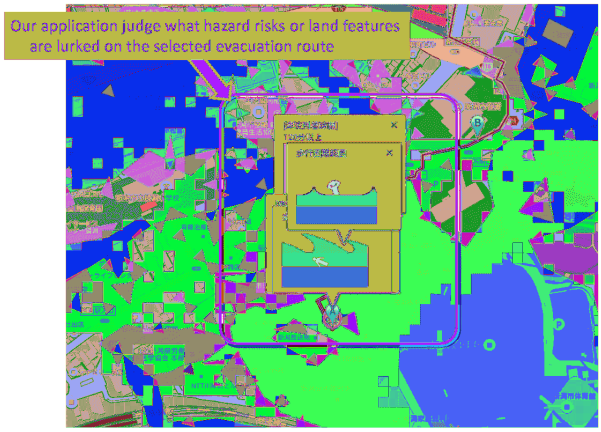
This application detect "Shortest Route" from start-point through 1st goal to 2nd goal.

This application evaluate transition of elevation on users' detected route dynamically.

This application suggest the minutes should be taken to walk to each goal.



This application evaluate hazard risks around the route.



Development of a Management Training Program for Supporting Life Recovery Process at the Time of Disaster based on the Idea of VMDB System

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INTRODUCTION. In the event of a disaster in Japan, local governments provide many types of administrative services to victims. Before the provision of these services, victims have to be identified and apply to the support programs. Victims are identified on the basis of building inspections for the assessment of building damages. The results of the building inspection are compiled in a database and certification of the degree of building damages are in turn granted to the victims.
Previously, a basic database was constructed to manage the certifications for the degree of building damages. The life recovery support system, VMDB, using the survivors' ledger comprehensively assists local governments, in the wake of a disaster, with helping disaster victims rebuild their lives, including the issuance of disaster victim certificates. It has been developed through an industry-academia collaboration among Kyoto University, Niigata University, NTT, InterRisk inc and others. The system makes it possible to quickly and fairly assess a significant number of damaged structures, and also includes programs to train the inspectors required for these assessments.

MANAGEMENT TRAINING PROGRAM. As the target of the ward City staff of Tokyo, in the opportunity to carry out continuous training to foster the core staff that can management up to the victims ledger leverage from damage authorized investigation, has developed a training program, Training was carried out in six courses. This program consists mainly of two of the contents of the next:
(1) Training for the victims life rebuilding support business management in line with the project management methods as follows; 1) Overall picture of project management in supporting life recovery process: Victims life reconstruction realities of support and an overall picture of the support system to organize the five components was commentary, 2) Inspect Building Damage: The positioning of the building damage certification survey business, it is an object of the business, certification standards, after explaining about the investigation process or the like, to take advantage of the pattern chart, etc., were carried out exercises of damage certification, 3) Register Inspection Results: After explaining the significance and mechanisms of the digital data of the questionnaire, questionnaire of creating exercises, and a reading demonstration by actual equipment were carried out, 4) Issue victims' certificate: Afflicted certificate issuance significance of the system, business flow, method of operation, describes the system configuration, using the afflicted certificate issuing system experientially, 5) Afflicted certificate issuance management: For afflicted certificate issued explains the need for performing a space designed in consideration of the business flow, the estimation of the concentration issue period, the study of the venue layout was carried out, 6) Life recovery support services management: After describing in terms of consultation and practical person in charge for the business for the business content of the life rebuilding support, it was role-playing exercises divided into victims auditors and practitioners auditors.
(2) Constructing WBS of the victims life rebuilding support business management
The WBS, hierarchically in detail the business, by structuring, is intended to facilitate the management. To manual the disaster response operations with a hierarchical structure, it is

necessary to clarify the janitorial structure of life rebuilding support services. To municipal officials who received the training, it was carried out WBS created on the life rebuilding support business.

FUTURE PLANS. Promote the content of the literacy hub towards the use of in accordance with the situation of the local government, promote the expansion of variation.

Keywords: Management Training Program, Supporting Life Recovery Process, Recovery, Urban Resilience

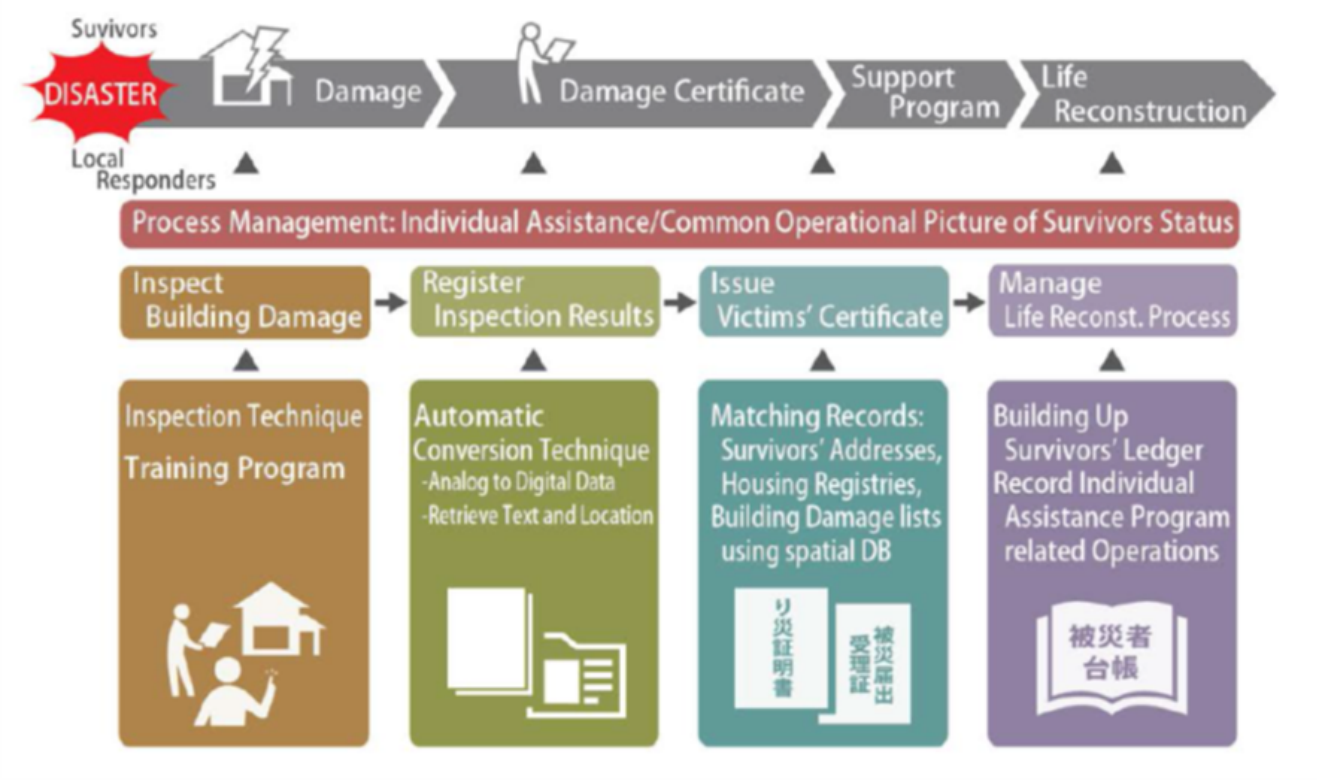

Fig. The Outline of the Life Recovery Support System, VMDB

The trial which presupposes the surface ground motion using underground seismographs

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We have been constructing an ultra dense seismic observation network; Metropolitan Seismometer Observation Network; MeSO-net. MeSO-net consists of 296 seismic stations. The signals from seismometers are sampled 200 Hz by a 24-bit analog to digital converter at the bottom of 20m-borehole. The surface ground motion differs from the waveform observed at the underground. Then, we tried presumption of the surface ground motion using an underground seismograph. The present study is supported by two Special Projects for Earthquake Disaster Mitigation in Tokyo Metropolitan Area and reducing vulnerability for urban mega earthquake disasters from the Ministry of Education, Culture, Sports, Science, and Technology of Japan.

Keywords: Metropolitan area, urban earthquake, intensity

Construction of historical document database for damaging earthquakes in Kanto region during the early modern period and felt reports of the 1855 Ansei Edo earthquake in the areas outside Edo City

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We are constructing historical document database for damaging earthquakes which occurred in the Kanto region since the 17th century based on previously-published sourcebooks, as a part of the Special Project for Reducing Vulnerability for Urban Mega Earthquake Disasters. Collection and analysis of descriptive contents of historical records are important for mapping damage distribution and estimating the earthquake sources of non-instrumental periods. Survey and collection of historical earthquake records have started in the beginning of the 20th century, and the collected historical records are now compiled as 35 volumes of sourcebooks (the total pages of 28,000). However, not only contemporary historical documents but also various kinds of historical materials such as excerpts from reports and documents describing histories of autonomous community are mixed in these sourcebooks. Therefore, we need to select only reliable historical records, and then emend the descriptions by tracing back to the original documents. We use the XML (eXtensible Markup Language) for mark-upping documents as same for previous database such as “Database for all historical documents in the ancient and medieval ages in Japan” and “Historical earthquake database in high strain rate zone” under the project “Multidisciplinary research project for high strain rate zone” of the MEXT, Japan.
We also conducted document surveys and analyzed historical documents for the Ansei Edo earthquake, which occurred on the 2nd day of the tenth month on 2nd year of Ansei era (November 11th, 1855 on the Gregorian calendar) and caused severe damage in and around Edo City, the former Tokyo Metropolis. We collected new historical records in Chiba prefecture (Muragishi and Satake, 2015, Disaster and Reconstruction and Documentation), and re-examined previously-published historical records in Ibaraki and Kanagawa prefectures (Muragishi *et al.*, 2016, ibid). We also carefully re-examined the felt reports in distant areas from Edo based on previously-published sourcebooks. We selected reliable historical documents describing the time of ground shaking which are consistent with the occurrence time of the Ansei Edo earthquake, and estimated the seismic intensity. On the locations where the felt reports were described, we identified current names and locations (longitudes and latitudes) using other historical documents, contemporary pictorial maps, and literature of Japanese historical studies, and constructed seismic intensity map for this earthquake.
Acknowledgment: This study was conducted as a part of the Education, Culture, Sports, Science and Technology Ministry funded research "Special Project for Reducing Vulnerability for Urban Mega Earthquake Disasters ".

Keywords: historical earthquakes, earthquake historical documents database, 1855 Ansei Edo Earthquake

Construction of Relationship between Fourier Amplitude Spectrum and JMA Seismic Intensity

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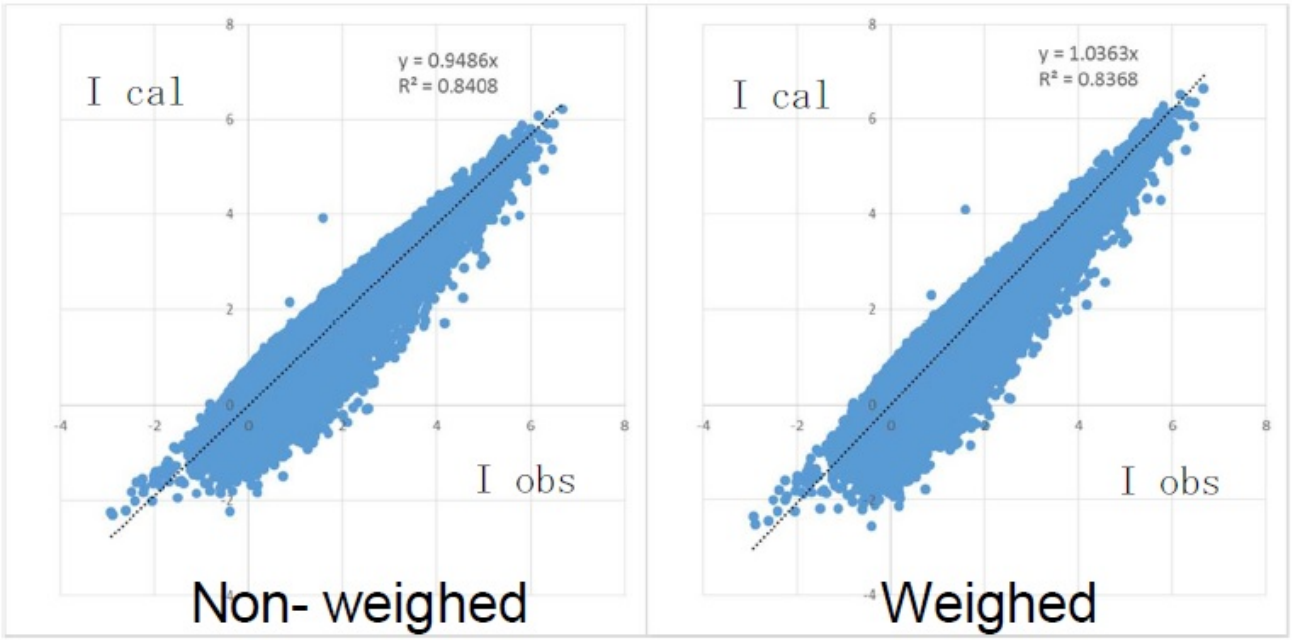
The relation between JMA seismic intensity and PGA, PGV or response spectrum has been studied by many researchers (e.g. Sakai *et al*, 2004, Fujimoto and Midorikawa, 2010). In this study, we derive the relation between the JMA seismic intensity and Fourier amplitude spectra.
We used 178,728 strong motion records of K-NET recorded from May 1996 to June 2011. Fourier amplitudes are obtained at the frequency of 1-10 Hz by estimating the average amplitude every 1Hz within a ±0.5Hz range. We used the linear relation between the Fourier amplitude spectrum FS(f) and seismic intensity I as follows,
I = sum[A(f)*logFS(f)] + B
where, f is frequency; 1-10 Hz in every 1Hz, A(f) and B are unknown parameters.
We used the least square method to obtain the unknown parameters. However, taking into consideration previous studies on frequency distribution of seismic intensity, and because the number of lower intensity data is overwhelmingly larger than that of the higher intensity data, we also adopted the weighted least square method. The relation between frequency distribution n(I) and seismic intensity I at a certain observation station is generally written as log n(I) = a –b*I (Utsu, 1999). We used the value of b=0.5, and used 1/ n(I) for weights in the weighted least square analysis.
Comparing the calculated intensity (Ical) obtained by FS(f) to the observed intensity (Iobs) obtained directly from the seismic records, we found that the weighed least square method fits the observations better than the non-weighted method at higher seismic intensities. The slopes of the regression line based on Ical and Iobs are just about 1 (45 deg. in the figures). This means that the results of the least square analyses are plausible, while the distribution of the plots based on Ical and Iobs may show some bias.
Seismic intensity data are essential in order to estimate the source parameters of historical earthquakes, because no instrumental records exist in this period. It is preferable to calculate the seismic intensity distributions in a broad area, because the seismic intensities do not always display a concentric distribution. This kind of abnormal intensity distribution phenomenon is caused by inhomogeneities of the seismic quality factor Q. We developed a method by which strong ground motions can be predicted considering a 3-D attenuation structure (Nakamura *et al*., 2009, 2015). Using this prediction method we can obtain the Fourier amplitude spectrum at a certain station. Thus we are able to simulate seismic intensities considering a 3-D Q structure, using the relationship between the JMA seismic intensity and Fourier amplitude spectra obtained in this study. In addition, several studies have obtained a 3-D Q structure using the t* method (e.g. Panayotopoulos *et al*., 2015). Since Fourier amplitude spectrum can also be calculated by this method, seismic intensity can be obtained using the relation between the JMA seismic intensity and Fourier amplitude spectra proposed by this study.
Acknowledgments: This study was supported by the Special project for reducing vulnerability for urban mega earthquake disasters from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

Keywords: Fourier Amplitude Spectrum , Seismic Intensity, K-NET



O-C の平均と標準偏差(赤字が良好の部分)

Data		Non-weighted	Weighted
All	ave	0.000	−0.109
	1σ	0.351	0.372
Iobs≧3	ave	0.350	0.067
	1σ	0.336	0.335
Iobs≧4	ave	0.461	0.124
	1σ	0.343	0.342
Iobs≧5	ave	0.504	0.108
	1σ	0.347	0.342
Iobs≧6	ave	0.651	0.203
	1σ	0.309	0.315

図1　回帰係数を用いた予測と観測の比較

Fig.1 Comparison between Iobs and Ical

A new model of P ans S wave attenuation structure for the Tokyo Metropolitan area using the MeSO-net station network

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In recent years the development of dense seismic networks in Japan has enabled high quality observations of instrumental intensities. The seismic intensity generally decays linearly with distance. This approximation is not always accurate, since the amplitude of short period ground motion decays with focal distance and is affected by the 3D attenuation structure along the path and in addition displays frequency dependence. In order to accurately simulate the seismic intensity distribution, we need to account for the non linear attenuation of seismic waves along the path. The instrumental seismic intensities inside the Kanto basin observed at the Tokyo Metropolitan Seismic Observation network (MeSO-net) and Hi-net stations display unusual distribution patterns, with peak intensities observed several km away from the epicenter rather than at the stations closer to it. In order to understand the source of this intensity distribution, we estimated the theoretical instrumental intensities using a 3D attenuation structure and compare it to the observed intensity distribution. We first estimated a 3D attenuation structure using the spectral decay of seismic waves, by fitting the observed seismic wave spectrum to a theoretical spectrum using an ω^2 model. The obtained model suggests Q values of 50~100 inside the Kanto basin and low Q values < 300 in the area where the Philippine Sea plate meets the upper part of the Pacific plate. In addition, we find that there is little attenuation of seismic waves in the middle crust area of the Honshu island bellow the northern Chiba and Ibaragi prefectures, with Q values greater than 600.
We then use an ω^2 model in order to estimate the source acceleration spectrum of several earthquakes occurring below the Kanto basin at depths ranging 30~80 km and to derive the PGA for P and S waves. We compared the observed PGA at the MeSO-net stations to the calculated PGA by our model. In order to estimate the observed PGA, we took a 4 sec window starting from the P or S wave arrival, and looked for the highest acceleration inside this window. The PGA values are moderately low west of the epicenter and highest in an area 20 km to the east of it for earthquakes occurring below the northern edge of Tokyo bay on the Pacific plate. These earthquakes are located exactly below the area were our model displayed significantly low Q values. Seismic waves passing through that area should be highly attenuated. This could be a possible explanation for the observed pattern of the intensity distribution. Although we are able to simulate the general trend in the PGA distribution, our model failed to exactly match the observed amplitudes. On the other hand the PGA distribution of shallow earthquakes does not exhibit a similar anomalous pattern. The distribution for both the observed and estimated PGA, for shallower earthquakes that probably occurred in the upper part of the Philippine sea plate, is characterized by amplitudes that drop almost concentric with increasing distance from the epicenter. Our attenuation tomography results suggest high Q values for the upper part of the crust. As a result, seismic waves passing through this area are very little attenuated. We also achieved better match of the observed and calculated PGA amplitudes in this case.

Keywords: Attenuation, Tomography, MeSO-net

Modelling of wooden houses in Furukawa district based on damage states during 2011 Tohoku Earthquake

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In case that building structures are subjected to a strong earthquake, both the strength of the building structure and the ground property greatly affect their damage level. Even if the buildings are closely located in a small area, it is possible that the difference of the velocity structure of subsurface layers divide their damage states significantly. Numerical simulation can be a powerful tool to give an explanation for spatial differences of actual damage in such a local site, however, it often becomes a task to introduce appropriate numerical models; it requires not only to set appropriate structural parameters of buildings but to estimate ground properties over the targeted area. Particularly with respect to ground properties like velocity structures, available information over a targeted area is limited in most cases.
Furukawa district, Miyagi, Japan, was subjected to the 2011 off the Pacific coast of Tohoku earthquake (the 2011 Tohoku earthquake) and then some of wooden houses in particular areas were severely damaged. Goto et al. (2012) established a temporal network of seismometers (Furukawa Seismometer Network, FuSeN) in the area, that is very high density networks using more than 30 accelerometers with a spatial interval of about 100 m. By analyzing the earthquake records and ambient vibration records observed by the FuSeN, Goto et al. (2016) proposed a model of local velocity structure in Furukawa district.
Using the velocity structures proposed by Goto et al. (2016), we estimated earthquake motions at each location in Furukawa district and calculated seismic responses of the wooden houses during the 2011 Tohoku earthquake. As both the detailed structures and the exact age at the time of the wooden houses were unclear, we modeled the story stiffness by shear springs and set three types of mass and stiffness model according to Building Standards Act of 1959, 1981 and 2000. Accelerations on the ground surface at each location, which were used as input earthquake motions, were calculated from both linear and nonlinear analyses to discuss the influence of soil nonlinearity on the spatial distribution of seismic damage. From the analytical results for each calculation case, this study examined the possible structure types of wooden houses and settings of analytical conditions that can explain the damage states over the area.

Keywords: damage analysis, Tohoku earthquake, wooden house

Time-dependent stress change in the Kanto region due to 2011 Tohoku earthquake, Japan, considering viscoelastic relaxation in the asthenosphere and afterslip

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The 2011 M9 Tohoku earthquake, Japan, was the fourth largest earthquake among ever observed, which caused broad deformation and abrupt change in seismicity in the surrounding regions. The Kanto region is located in vicinity to the southern end of the source area of the M9 earthquake, and possible triggering of rupture of blind thrusts and volcanic activity is concerned. In order to understand the postseismic crustal activity, it is important to investigate regional stress state. Mechanisms of postseismic crustal activity are considered to be afterslip which occurs around the mainshock slip area and viscoelastic relaxation in the asthenosphere. We construct a finite element model which accounts for both mechanisms to calculate stress. Model region is defined by a cuboid of 3400 km x 4600 km x 700 km, which includes the Kuril, Mariana, and Ryukyu arcs. We made the plate boundaries by interpolating the plate boundary models from previous studies. The model region is divided by 1000,000 linear tetrahedral elements of the size of 5-100 km. Slip region is divided into 480 subfaults (28 km x 28 km in average) and displacement response for each subfault is calculated. Coseismic slip and afterslip is obtained by the following procedure with inversion of GPS and sea floor deformation data. First, we obtain coseismic slip by inversion of the coseismic displacement data. The coseismic slip distribution is put into the FEM to calculate postseismic displacements. Comparing calculated and observed postseismic displacements, we obtained a viscosity structure explaining the observation in a trial and error way. We assume that residual displacements are caused by afterslip, which is obtained by inversion of the residual. Then, the coseismic slip and afterslip are put in the FEM again to calculate the Coulomb stress on the blind thrusts in the Kanto region. Calculated Coulomb stress is 0.3-0.4 MPa in 10 years, which is a significant value for affecting the seismicity. Most of the stress change is caused by the viscous relaxation in the asthenosphere, indicating its importance. On the other hand, stress change due to the afterslip is ~0.1 MPa.

Keywords: 2011 Tohoku earthquake, Crustal deformation, Finite element modeling, Viscoelasticity, Afterslip, Northeast Japan arc

