20 Years of K-NET

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Strong motion observation in Japan has been operated since 1950's together with the development of the SMAC strong motion sensors, which succeeded in recording the ground motions of the 1968 Tokachi-oki and 1978 Miyagi-oki earthquakes. Near-fault ground motions were observed during the 1995 Hyogoken-nanbu (Kobe) earthquake, however, several problems were posed regarding initial response. After the 1995 Kobe earthquake, the Japanese strong motion observation was drastically stimulated. Many Japanese organizations such as the National Research Institute for Earth Science and Disaster Prevention (NIED) have made a lot of efforts to improve the quality and quantity of the seismic observations in Japan. Since 1996, NIED has been in charge of the operation of two strong motion networks: K-NET and KiK-net. K-NET consists of about 1000 stations with 3-component acceleration strong-motion seismographs on the ground surface. KiK-net consists of about 700 stations with 3-component acceleration strong-motion seismographs both on the ground surface and at the bottom of the boreholes. NIED is a pioneer institution in Japan to releasing all digital data for free through the Internet immediately after an earthquake, and nowadays this open-data policy is becoming a common practice among the seismological field. NIED also developed new instruments of K-NET and KiK-net for upgrade with new technology. The first, second, and third generations of NIED accelerometers are capable of measuring up to 2000, 4000, and 8000 gals, respectively. The first generation, K-NET95 (Kinoshita, 1998) and SMAC-MDK (Aoi et al., 2004), adopted a dial-up system in which the Data Management Center (DMC) of NIED called to stations and collected data via telephone line after earthquakes. The second generation, K-NET02/K-NET02A (Fujiwara et al., 2007) and KiK-net06 (Aoi et al., 2011), adopted a dial-out system in which stations automatically sent data to DMC after triggered. Real time seismic intensity (Kunugi et al., 2008, 2013) is also calculated at stations. The third generation is K-NET11/K-NET11A and KiK-net11/KiK-net11A (Kunugi et al., 2014). K-NET02/K-NET02A has been officially approved as a seismic intensity meter by the Japan Meteorological Agency (JMA). Step-wise noise was improve by using the JA40GA sensor with quarts hinge, which can measure the long-period components. In the third generation, 4-component sensors are installed to ensure the accuracy of the acceleration measurement based on lessons from severe situation in the 2011 Tohoku earthquake. K-NET and KiK-net have recorded the JMA seismic intensity of 7 four times, intensity 6+ and 6- 188 times, and over 1000 gals 42 times including 4022 gals during the 2008 Iwate-Miyagi earthquake. Because of the low-frequency occurrence of large earthquakes, strong motion has been commonly observed by event triggering system, which requires connection of the telephone-line only during the data collection. To advance the rapidity and reliability, continuous observation is one of the most likely options. Data recorded by an event triggering system provides important information of past earthquake and helps to assess the seismic hazard and risk of a future earthquake. With a continuous observation system, owning to the rapid progress of information technologies, we would soon be able to fully monitor ground motions in real time and thus directly contribute to mitigate seismic disasters. Strong motion observation has been operated over years due to selfless efforts of our frontrunners. Even though recent trend regards the short-range research progress as important, it is also quite important to incorporate with new technology to ensure recording of less frequent but very important events occurring once per years or decades, such as the 1995 Kobe or 2011 Tohoku earthquakes.

Keywords: K-NET, KiK-net, Strong motion observation

Utilization of K-NET data in Central Disaster Management Council

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Central Disaster Management Council is making master plan for disaster prevention and deliberating important part about disaster prevention. And Central Disaster Management Council establishes committees for technical investigation to investigate a technicality. We are able to find mentioning about use of K-NET in the reports which the committees for technical investigation on earthquake disaster issued. For example, the records which acquired by K-NET are compared with synthesized waveforms on the report issued by the “Committees for Technical Investigation on Countermeasures Against Tokyo Inland Earthquake”.Observed data by K-NET are useful to evaluate the subsurface structures. Yokota et al. (2011) evaluated the amplification of long-period component of seismic records, and confirmed that the natural period which calculated from velocity structures related to the amplitude of long-period component of ground motion. The relation was that the longer the natural period at the observation station was, the larger the amplification of long-period component of observed record was.We introduce the trend of use of the above-mentioned K-NET data.

Keywords: K-NET, disaster mitigation, strong motion

Application of K-NET records to development of design long-period ground motions

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Long-period ground motions in the period range from 2 to 10 s are influential to super high-rise buildings and base-isolated buildings. In order to develop design long-period ground motions for these buildings we studied long-period ground motions from 2008 to 2012 with Building Research Institute in the "Promotional project for upgrading the building standards" under the auspices of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Based on these studies MLIT called for public comments on "Countermeasure plan for super high-rise buildings against long-period ground motions caused by mega-thrust earthquakes along the Nankai Trough" on December, 2015. In this paper we mainly show technical and academic results on empirical long-period ground motion predictions using K-NET and the other strong motion records.
Firstly we develop ground motion prediction equations (GMPEs) of response spectra and Fourier phase spectra in the period range from 0.1 to 10 s using many K-NET, KiK-net, JMA-87 and JMA-95 records. About 10000 earthquake-station pairs of hypocentral distance X < 400 km for 51 subduction-zone earthquakes with M_J6.5-M_J8.2 and depth < 60 km and 6000 earthquake-station pairs of X < 350 km for 26 crustal earthquakes with M_J6.0-M_J7.3 are used. The GMPE of response spectra is modeled by rupture distance, Mw^2 and Mw considering with saturation effects on distance. The GMPEs for average and variance of group delay time which is the differential of Fourier phase spectra within narrow frequency bands is modeled by X and seismic moment. The GMPEs for average and variance of group delay time enable us to empirically generate time history. For subduction-zone earthquakes, we get different site factors in the Kanto basin for the earthquakes of the Pacific plate and the Philippine Sea plate, respectively. The site factors for earthquakes of the Philippine Sea plate are larger than those for those the Pacific plate due to 3D effects of the Kanto basin.
The site factors are obtained at strong motion stations with about 10-20 km intervals. Since the site factors in the period range from 1 to 10 s are found to be different from 1D amplification factors for S waves, we develop a regression model of site factors to predict them at any construction sites in three major urban regions. The regression model is developed using Tz, which is 1/4 of the natural period from seismic bedrock to engineering bedrock calculated from the deep substructure model with about 1 km grid space by HERP. The site factors are empirically represented by a bi-linear function of Tz well. We show that the bi-linear function can be interpreted from medium responses of surface waves. However Tz is not enough to represent the site factors in the area where the deep subsurface structure abruptly changes such as Kobe area. In that case we correct Tz so as to empirically consider 3D effects on site factors.
Time history of ground motions in the period range from 0.1 to 10 s can be predicted by the developed method using outerfault parameters. For large earthquakes whose faults are composed of several segments, time history is generated by summing up the time history for each segment considering each rupture starting time. This method is verified by simulating strong motion records of K-NET and KiK-net stations for the 2011 Tohoku earthquake. We also confirm that long-period ground motions predicted by this method are consistent with those predicted by 3D-FDM by HERP for the Tokai earthquake, the Tonankai earthquake, and the Nankai earthquake.
Acknowledgments : The strong motion records observed at K-NET and KiK-net stations by NIED, JMA-87 and JMA-95 stations by JMA and a station at Kogakuin University are used in this study. The seismic moments determined in the F-net by NIED and Global CMT project and hypocenter information by JMA are used.

Keywords: K-NET strong motion records, Long-period ground motions, Ground motion prediction equation , Mega-thrust earthquakes along the Nankai Trough, Phase spectra, Super high-rise buildings

Long-Period Ground Motion of Tokyo Metropolitan Area during the Deep Event occurred off West of Ogasawara Islands

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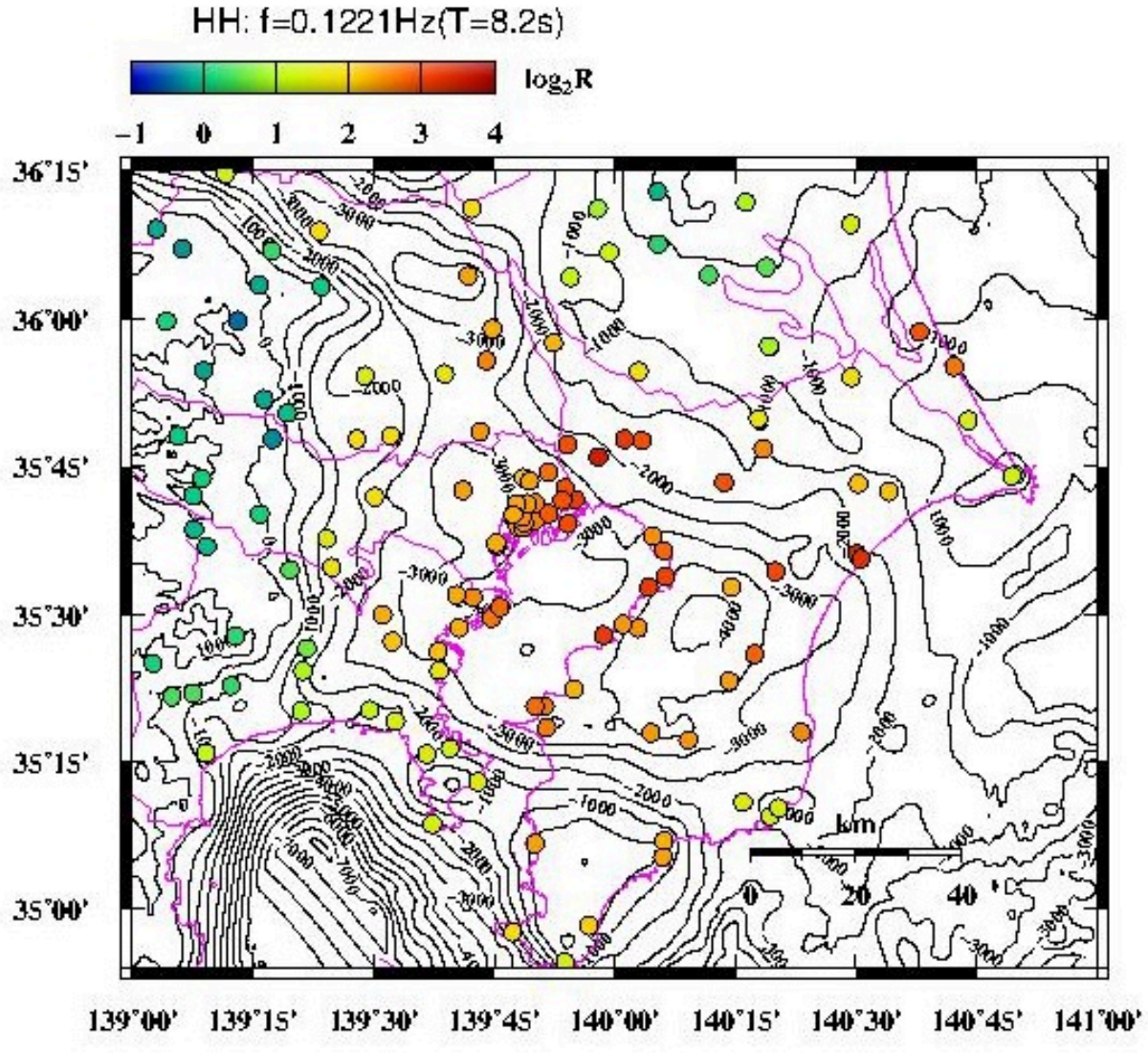
1. Introduction
The large earthquake with M8.1 has occurred in the west off Ogasawara Island at 628 km in depth on May 30, 2015. This event data give several merits for empirical site factor study of Tokyo Metropolitan area. Large magnitude means the high-SN ratio in long-period band. Deep epicenter means the incident wave was body wave with high incident angle. Long distance makes the radiation pattern effect small in the observation network area. In this study, the empirical amplification factor in long-period band of 2 to 10 s using the data observed in the Tokyo metropolitan area.
2. Data
The acceleration data observed by K-NET and KiK-net located in Kanagawa, Tokyo, Chiba, Saitama and Ibaraki prefecture were used in this study. The velocity data observed at the thermal power stations of TEPCO around Tokyo bay area were used, too. Almost K-net seismometers were triggered at S-wave and P-wave portion of the data was lost. It was not problem because the analysis target in this study was S-wave portion.
3. Propagation in sediment layers
The propagation characteristics of S-wave portion were checked by comparison of the wave forms between ground surface and the bore hole at KiK-net stations. Significant phase propagated from deep underground and reflected at ground surface. The time lag between the input phase and the reflected phase was coincident with the time calculated from subsurface velocity model.
The F-K spectral analysis of S-wave portion were performed using dense K-NET stations located in the east part of Tokyo. The result shows that the low-frequency wave propagation velocity was over 6km/s in horizontal direction. It means that the S-wave propagate from bedrock with high incident angle.
4. Spectral ratio to the rock site
First, the Fourier spectra were made from the S-wave portion of acceleration records with the time window of 81.92 s by FFT methods. The spectra were smoothed by Parzen window of 0.05 Hz width. Next, the Fourier spectral ratios were made by division of the ground surface data at each station by the ground surface data at TKYH13. TKYH13 is located in the Kanto Mountain in west of Kanto plain. At TKYH13, there are almost no amplification in lower frequency band than 1Hz from the bedrock with Vs=2500m/s at 100 m depth to ground surface. We can consider the record of TKYH13 the outcrop bedrock data in low frequency band.
The value of spectral ratio becomes bigger from the west station to the east station. The spatial distribution of spectral ratios at about 8 s and the distribution of the bedrock depth are almost conformable except for the southern part and northern part of Chiba prefecture. If a period becomes shorter, the correlation of spatial distribution of spectral ratio with the seismic bedrock depth is worse. This means that the short period ground motions was affected by the more shallow subsurface structure.
5. Discussion and conclusions
We compared the spectral ratios to TKYH13 in this study and the site amplification factors from the bedrock calculated from the subsurface structure models made from the past investigations. The results show that the spectral ratios were higher than the theoretical amplification factor in the Kanto basin. However, the spectral ratios between ground surface to the bedrock at each station

accorded with the theoretical ratio calculated from subsurface structure model. These results mean that the incident wave from the seismic bedrock at deep sediment stations were bigger than incident wave at TKYH13. This spacial change in the Tokyo metropolitan area may be given under the influence of the plate structure like the abnormality seismic intensity area.

Acknowledgments
We used the data of K-NET and KiK-net strong motion observation network of the National Research Institute for Earthquake Science and Disaster Prevention.

Keywords: Deep Event, Long-Period, Metropolitan Area, Body Wave, Spectral Ratio



Development of real-time earthquake damage information system using K-NET

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We develop a real-time earthquake damage information system that provides information by combining amplification characteristic data for subsurface ground accumulated in the course of the development of the Japan Seismic Hazard Information Station (J-SHIS), basic information on population and buildings, methods for predicting ground motion, methods for assessing building damage, and strong motion data observed by K-NET, KiK-net, local governments, and the Japan Meteorological Agency (JMA) in real-time. This system estimates spatial ground motion distribution in 250m-mesh from seismic intensity information sent at different timing for observation stations, estimates population exposure to seismic intensity and building damage using estimated ground motion as input, and provides information as “J-RISQ earthquake quick report” to users via Web (http://www.j-risq.bosai.go.jp/report/en/). The system estimation is based on intensity data obtained at different timing to ensure recency by updating results when it receives new data and updates results when it receives estimation results. We will improve the system for not only estimating damage situations but also confirming them by various type of information. In this study, we report on system outline and progress in developing building and population models covering the entire country of Japan, along with the development of methodologies related to damage estimation and situation assessment which are core components in the research and development of a real-time earthquake damage information system.

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Keywords: real-time, earthquake damage, K-NET

Improvement of Earthquake Disaster Response in Central City Area in Megacity using the Real-Time K-NET Data

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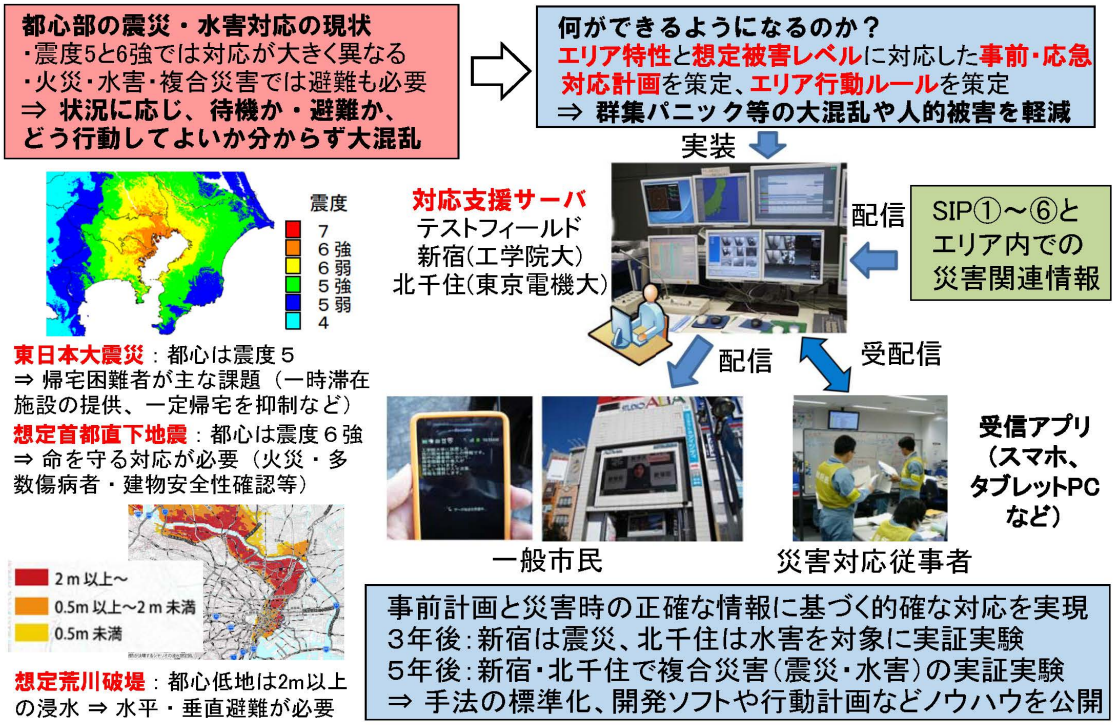
Although the JMA seismic intensities were 5 without major damage in Tokyo, its central city areas were thrown into confusion, because of the traffic jams and the huge number of commuters unable to get home. In order to prepare against larger-scale earthquake disasters in the central city area in Megacity, such as the Shinjuku Station area in Tokyo, we have been developing a series of the application systems, which consists of the pre-action area plan and rule based on the level of disasters, the information server and application software for portable PC and cellular phone, and earthquake disaster drill. We developed the prototype of the systems using the real-time K-Net data, and tested its effectiveness by a map exercise in the Shinjuku station area in 2015. We have been improving them, and test again by a drill in 2016.

Keywords: K-NET, Central City , Improvement of Earthquake Disaster Response, Complex Disater, Prior Action Plan and Rule



Current status of K-NET

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National Research Institute for Earth Science and Disaster Prevention (NIED) has installed K-NET95, K-NET02/02A, K-NET11/11A strong motion seismographs to observatories of K-NET. These seismographs were developed by NIED, employing state-of-the-art technologies. One of the features of K-NET02 and later models is their operating systems (Linux). Due to the OS, these seismographs are able to perform multi-functional operations. The operations are easily re-programmable. K-NET02/02A and K-NET11/11A share almost all of their programs.
NIED started a feasibility study for continuous monitoring of strong motion. As a part of this study, NIED had added new functions for continuous calculations and transmissions of strong motion to seismographs at observatories in Kanto and Tokai areas. Continuous monitoring of strong motion is useful for research and development of "Earthquake area alarm" (Nakamura et al, 2014). Also continuous transmissions are useful for robust recording of strong motion data.
In this presentation we will introduce current status of K-NET, focusing on K-NET11/11A seismographs and new observation system.
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Keywords: K-NET, Strong motion seismographs, Continuous monitoring of strong motion, Earthquake damage estimation, Earthquake early warning

