

SYNTHESIS OF STRONG GROUND MOTIONS FOR TOTTORI-KEN SEIBU EARTHQUAKE CASE

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A near field strong ground motion simulation was carried out for the Tottori-ken Seibu Earthquake (2000). The ground motions are simulated by the convolution scheme in time for source function and in space along rupture direction with the layered soil Green's function method based on the kinematic dislocation model. The synthetic motions based on the inversion information from the observed data are compared well with the Koufu and Nichinan station records. The response spectra analyses also show good agreement between observed and simulated motions. The 1-D wave propagation analysis is performed to interpret the amplification in the soil deposit.

Key Words : Ground motion simulation, Kinematic dislocation, Fault rupturing, 1-D Wave Propagation

1. INTRODUCTION

The Tottori-ken Seibu Earthquake $M_j=7.3$ occurred on October 6, 2000 in western Tottori Prefecture. Hypocenter depth was 11 km and PGA was recorded 927 gal in Hino city 8 km southeast of the epicenter. In Fig. 1, the location of the epicenter, the ruptured fault and the nearest record stations are shown.

The studies on recent earthquakes, the 1994 Northridge earthquake and the 1995 Hyogo-ken Nanbu earthquake, clarified that the characterization of the fault surface and the modeling of the wavefield are important factors for near source strong ground motion predictions.^{1,2)} Especially, in case of the shallow source earthquakes, the near surface geology apparently comes into view. To get the information about near surface geology, source parameters are extracted inversely from observed strong ground motions depending on the source model, and later it is attempted to the forward analysis for predicting the ground motions. A simulation method of near-source motions is developed by Takemiya and Goda^{3,4)} by taking into account the above considerations. The kinematic model is used for simulation. The solution method for the related moving Green function is the application of the Laplace-Fourier transform respectively to time and space.

In this study, it is objected to simulate near field

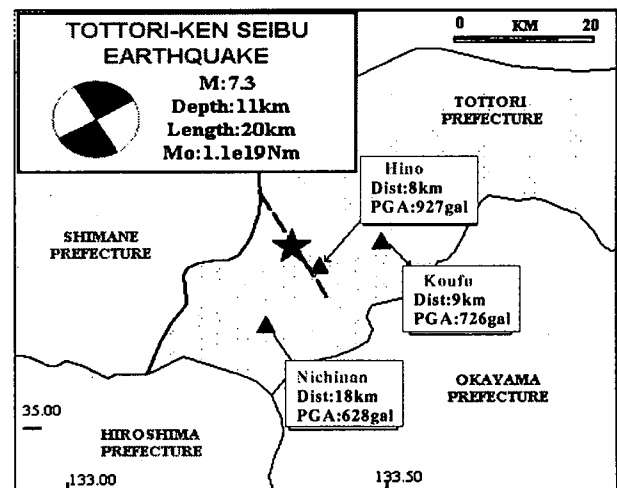


Fig. 1. Location of the observed record stations and fault

strong ground motions in view of inhomogeneous rupture mechanism due to fault rupturing in the Tottori-ken Seibu Earthquake case by taking into account the succeeding wave propagation path.

2. GROUND MOTION CHARACTERISTICS

Strong motion data (from Kik-net, K-net, PARI⁵⁾) associated with the mainshock of the earthquake have been analyzed to investigate the site response characteristics. In Fig. 2, the variation of the Peak Ground Accelerations with the epicentral distance is shown, comparing with the attenuation curve developed by Annaka and Yashiro⁶⁾.

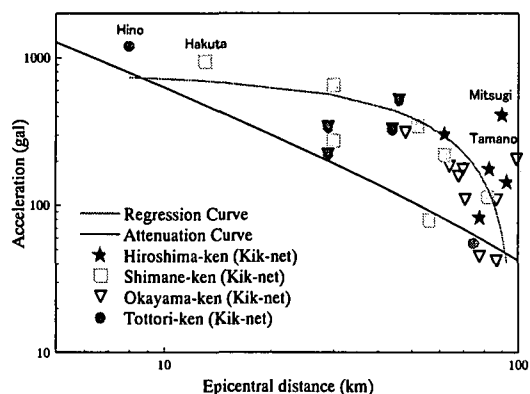


Fig. 2. Distribution of PGA with epicentral distance (Kik-net)

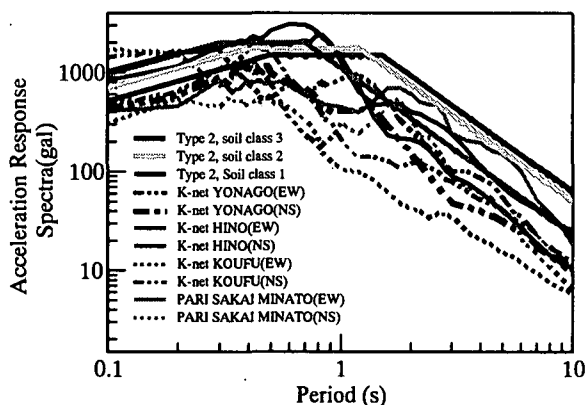


Fig. 3. Acceleration Response Spectra of observed records with Type II Design Spectrum

The ground motions which were recorded by the Kik-net in Hiroshima, Shimane, Okayama and Tottori Prefectures were used. As it is seen from the figure the observed Peak Ground Accelerations are decreased when the epicentral distance increases. However, in the Mitsugi and Tamano stations high PGA can be observed, although these stations are located far from the epicenter. This can be attributed to the local site conditions of those stations. In Fig. 3, acceleration response spectrum of observed records (Kik-net, PARI) are compared with the Japan Highway Bridge Specifications Type II Design Spectrum. Here, it can be observed that the acceleration response spectra of all records except Hino station record are within the design limits. The Hino station record shows excessive response between 0.4 – 1.0 s comparing to design spectrum. The 1-D wave propagation will be performed later to interpret this situation.

3. FAULT RUPTURE MODEL

Source mechanism studies have shown a left lateral strike slip faulting. The rupture propagated upward and bilaterally. The traced fault length was about 20 km, and the maximum dislocation was about 3m⁷⁾. According to waveform inversion

Table 1. Fault rupture model parameters

Earthquake Parameters				
The Seismic Moment: $M_0=1.1e19Nm$				
The averaged dislocation: 2.4 m				
Hypocenter: (35.275N 133.35E, Depth 11 km)				
Seismic Parameters				
Fault mechanism: (Strike,Dip,Rake)=(150, 87, -7)				
Fault Area (km^2): 20km * 10km				
Rupture Velocity (V_r)= 2.3 (km/sec)				
Rise Time (T_r) = 2.2(sec)				
Soil Parameters				
Layer No.	Thickness (km)	S Wave Velocity(km/s)	Poisson's Ratio ν	Density (t/m^3)
1	1.0	1.0	0.280	2.1
2	Infinite	3.5	0.250	2.8

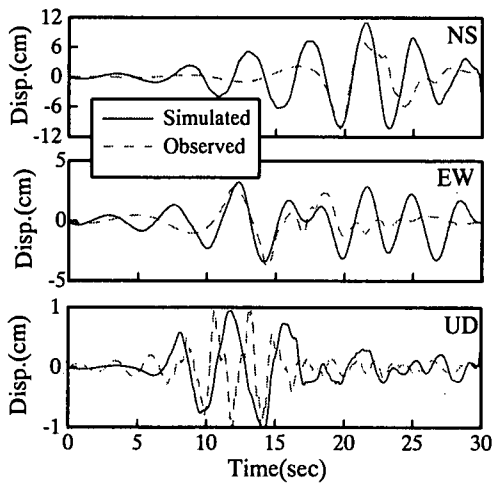
results⁸⁾ the fault rupture model was formed in a two-layered soil whose parameters are presented in Table 1. The rupture progress was controlled by a radial proceeding model of a constant slip rate.

4. SIMULATION METHOD

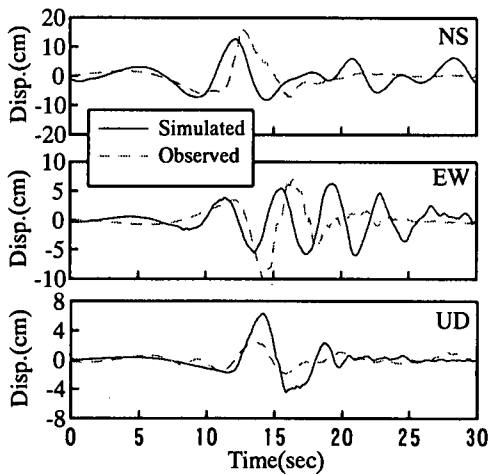
The kinematic fault rupture mechanism (dislocation theory), replaced by the equivalent force action on fault area, is solved for the near-source strong ground motion simulation. The 3-dimensional wave analysis is formulated for an elastic media that includes the fault rupturing. The Laplace transform with respect to time and the Fourier transform with respect to space on the horizontal plane are used for the moving Green Function computation. For the rupture process, the double time convolution integral was implemented by the slip function and space propagation. The inverse Laplace transform is performed analytically and the inverse Fourier transform is carried out numerically when replaced by the discrete wave number method. The detail explanation for the methodology can be found in references^{2,3,4,9)}.

5. SIMULATION RESULTS

It is focused in this study to simulate the Koufu, and Nichinan records. The computation results are filtered in order to extract only the essential response features. The trapezoidal filtering window is used for the final evaluation of responses, which specifies (0.05-0.1 Hz) for high-pass and (20.0-21.0 Hz) for low-pass cutoff frequencies. As it is seen from Fig. 4, the peak displacements for Koufu, and Nichinan records are observed in -NS- directions. Nichinan station shows the larger displacement with 16 cm around 12 s.



(a) Koufu



(b) Nichinan

Fig. 4. Simulated and Observed motions

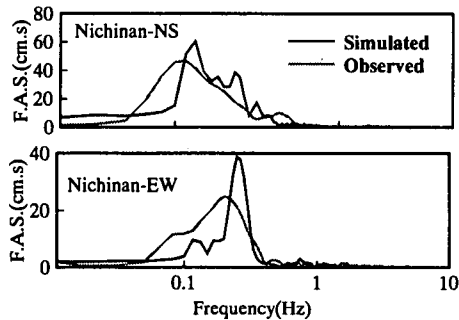


Fig. 5. Fourier Amplitude Spectrum of Simulated and Observed motions in Nichinan and Hino station

In Fig. 5, the Fourier Amplitude Spectrum of the Nichinan station -NS- and -EW direction records show that frequency contents of simulated motions mostly fit that of the observed ones. In Fig. 6, Acceleration, Velocity and Displacement Response Spectra of Koufu and Nichinan Stations' observed and simulated records are presented. Response Spectra of the observed and simulated motions show good matching in each direction for each component. Considering the design spectrum in Fig. 3, here we can observe from Acceleration Response spectra in Fig. 6 that both simulated and

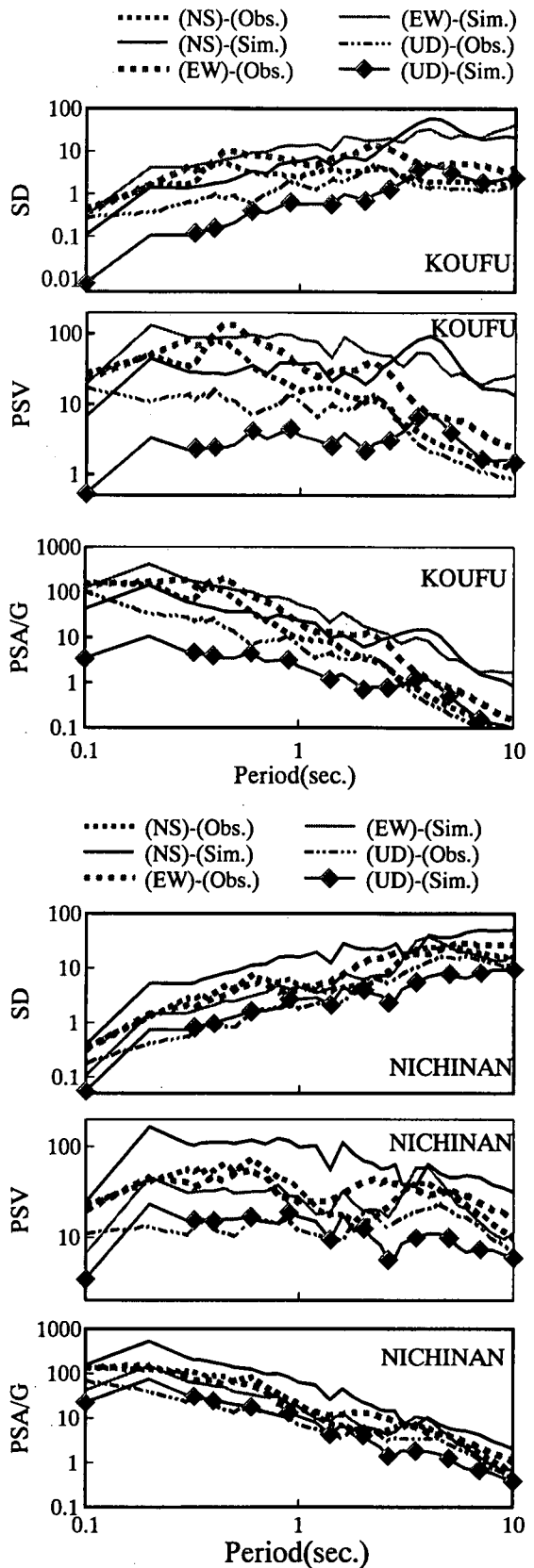


Fig. 6. Observed and Simulated Acceleration, Velocity, Displacement Response Spectra

recorded motions are within the design limits.

6. WAVE PROPAGATION SIMULATION

In order to interpret the amplification due to the

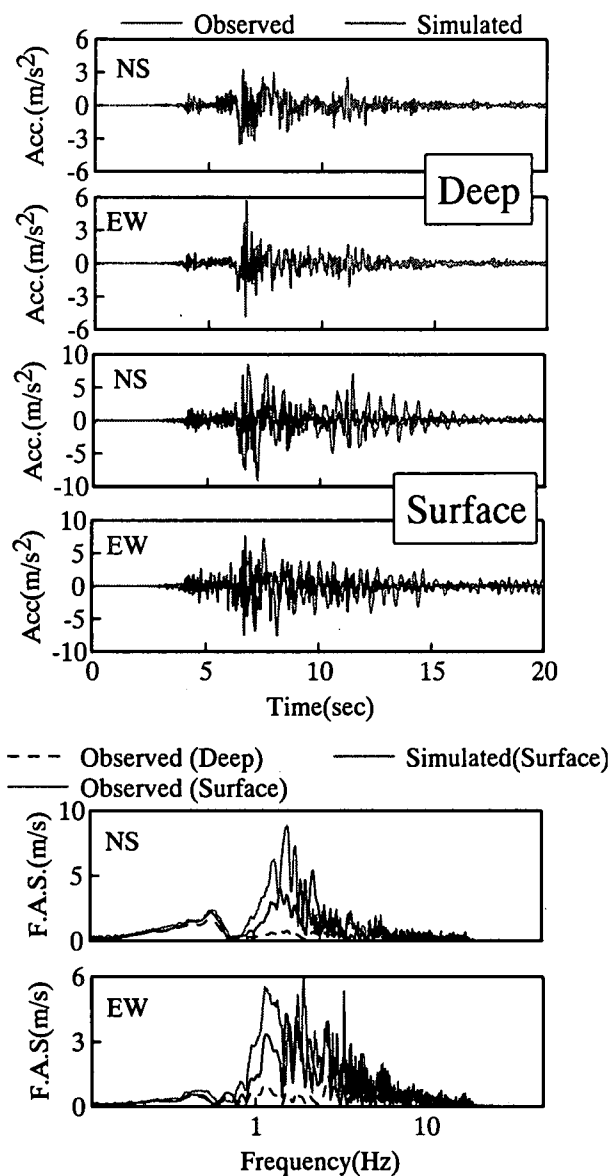


Fig. 7. 1-D Wave Propagation simulation at Hino station

shallow soil deposits, the 1-D shear wave field assumed for Hino station. The observed motion at the depth of 100m used as an input motion. In the upper part of the Fig. 7, observed deep motions are shown. In the middle part, observed and analytical motions on the surface are presented. They agree well for both horizontal directions. Although the peak acceleration at the depth is higher in -EW- direction, at the surface it is observed in -NS- direction. This indicates that amplification was larger in -NS- direction. The Fourier Amplitude Spectrum of the observed motions at the surface and deep, and analytical motion at the surface are also shown in the lower part of the Fig. 7. Here, good agreement can be observed. In the low frequency part, all 3 motions have the almost same peak, however in the frequencies around and larger than 1 Hz the amplitude of the surface motions becomes larger. This is the frequency band that amplification occurred.

7. CONCLUSION

The near field strong ground motions were simulated for Tottori-ken Seibu Earthquake (2000). Regarding the simulation of Koufu, Hino and Nichinan station records, radial proceeding model was used as a rupture model. The findings could be summarized as follows;

1. As a characteristic of the near source strong ground motions a sharp build-up could be observed in displacement motions.
2. Acceleration response spectra of the recorded and simulated motions were within the Type II Design Spectra limits.
3. Simulated and observed ground motions showed a good agreement on displacement component in all directions.
4. The response spectrum calculations showed that observed and simulated motions have a good matching especially in the major part of the motions.
5. The 1-D wave propagation analysis clarified the frequency band where the amplification in the soil deposits occurred. In the lower frequency part, the same peak could be obtained for the Deep and Surface motions. The difference around 1Hz can be explained as the amplification of the soil deposit.

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