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MODELLING OF DEEP BASIN STRUCTURE ANDNUMERICAL SIMULATION OF GROUND MOTIONS AT LONG PERIODS IN OSAKA PLAIN

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SUMMARY

It is important to evaluate long period ground motions considering the large-scale ground topography for the seismic design of long-period and/or base isolation buildings. The Osaka plain that has one of the largest cities in Japan is focused on the evaluation of ground motions. This paper describes modelling of the deep basin structure in the Osaka plain and simulation analyses using 3 dimensional Finite Difference Method(FDM).

The 3 dimensional ground model of the Osaka plain has been proposed by some researchers. This paper refines and extends the existed model. The area of modelling is range 90km in north-south by 100km in east-west, and divided into 1km mesh. Each mesh has material properties such as P-wave velocity, S-wave velocity, density and damping factor based on the various investigations.

3D FDM is used to simulate the ground motions propagating in the Osaka plain. Two FD models are used for analyses. One is based on the model by Miyakoshi et al(1997), the other is re-constructed with recent investigation data. Simulation results could verify that the basin structure was appropriate. Comparing the calculated waveforms with the observed ones, it was found that the structure of a proposed model well simulated the underground topography. However, in the north and east area of the plain, where sedimentary layer structure is complicated, observation records are not simulated well. Therefore, it may be necessary to revise the model by taking in latest investigation results.

INTRODUCTION

The 1995 Hyogoken Nanbu(Kobe) earthquake indicated that the inland earthquake caused catastrophic damages to the urban areas and the deep basin structure affected the amplification of seismic motions. In order to reduce the earthquake disaster, it is important to spatially evaluate ground motions based on the 3 dimensional sedimentary structure. The long-period seismic motions for the skyscrapers and base isolation buildings should be precisely predicted to assure the seismic safety, especially, in the urban areas such as Tokyo and Osaka that have been developed at the alluvial plain

Ground motions can be evaluated by the product of the "source", "path" and "site" effects. Recent development of the numerical analysis technique and computer hardware performance would predict the long period ground motions including fault models. The "source" effect still depends on the inversion analysis. On the other hand, the detail deep sedimentary/basin structure is required to clarify the "path" and "site" effects.

The authors have constructed the 3 dimensional deep basin structure in the Osaka plain as focused on the long period seismic motions that the target period is longer than 2 or 3 second. The 3 dimensional finite difference analyses for the small earthquakes were also performed to verify the accuracy of basin structure model.

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MODELLING OF DEEP BASIN STRUCTURE IN THE OSAKA PLAIN

2.1 Smoothed Model

The Osaka plain consists of a typical basin structure; Rokko, Ikoma and Izumi Mountains surround the Osaka urban area and the oblique angle of the bedrock is steep toward the center of the plain. Many investigations such as seismic reflection survey, refraction survey and microtremors observation have been conducted in the Osaka plain. Kagawa et al.(1993) compiled the investigation data and proposed the Osaka basin model, which consists of 4 layers and covers the area about 72km square. Miyakoshi et al.(1997) recompiled the investigation data conducted after the 1995 Kobe earthquake. Their model is excellent for the first approximation as the Osaka basin model. However, it can not express the locally irregular shape of basin because of smoothed model by spline function.

2.2 Modification of Model

This paper proposes a refined Osaka basin model considering the latest investigation results and public materials on the Osaka sedimentary structure.

The following is the procedure of construction of the Osaka deep basin structure model. The layer parameters same as Miyakoshi et al. are used as shown in Table 1. The area of modelling is range 90km in north-south by 100km in east-west, and divided into 1km mesh. The boundary depths of layers of each mesh are presumed according to the investigation data shown in Figure 1. Some of the authors carried out microtremors array observations to obtain the fundamental materials for the prediction of strong ground motions. It was found that the horizontal/vertical spectral ratio (H/V ratio) was closely related to the predominant period of the sedimentary layers(Wakamatsu et al., 1996). These results were adapted to modify the depth of sedimental layers. The seismic reflection surveys conducted around Osaka-Kobe area, the Uemachi fault and Ikoma fault referred to the irregular shape of the basin.

Figure 2 shows the depth to bedrock of smoothed basin structure model by Miyakoshi et al.(call P-0 Model) and newly constructed model(call P-1 Model). Although both models are similar to the structure presumed by gravity survey, P-1 model can express the locally irregular shape of basin.

Table 1: Layer Parameters of the Osaka Plain

	Vp(km/s)	Vs(km/s)	Density(tf/m^3)
A-Layer(Upper Sedimental Layer)	1.60	0.35	1.7
B-Layer(Middle Sedimental Layer)	1.80	0.55	1.8
C-Layer(Lower Sedimental Layer)	2.50	1.00	2.1
D-Layer(Seismic Basin)	5.40	3.20	2.7

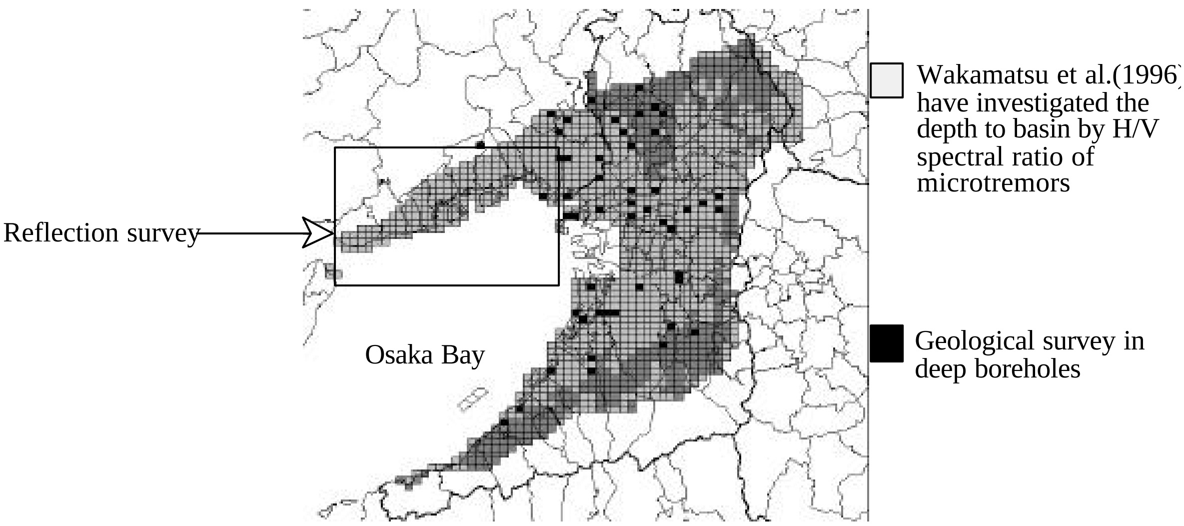
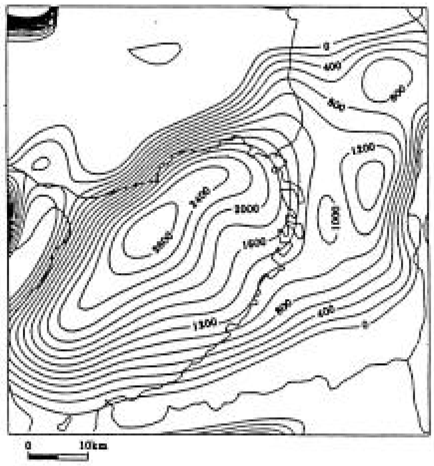
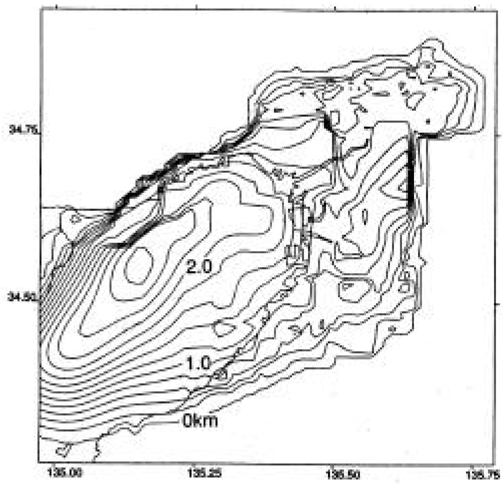


Figure 1: Investigation Data of the Osaka Plain





a) P-0 Model(Miyakoshi et al. **(b)P-1 Model**

Figure 2: Interpreted Depth to Bedrock

CHARACTERISTICS OF GROUND MOTIONS IN THE OSAKA PLAIN

Toriumi(1996) has pointed out that the strong motions with long duration in the coda part of S waves were observed in the Osaka plain. In the area of the Uemachi tableland, Matsunami et al.(1992) also pointed out that the coda part of the north-south component of seismic records of the earthquakes whose epicenter is the south might be the Love wave generated by the Ikoma Mountain. The coda waves, which reflected between the sedimentary layer and basin rock, appear after the main S waves on the soft soil layer at the Osaka Bay area.

The Committee of Earthquake Observation and Research in the Kansai Area(CEORKA) and Obayashi Corporation set the earthquake observation stations shown in Figure 3. The observed records with the epicentral distance are shown in Figure 4. The characteristics of the Osaka plain from these 2 earthquake records are as follows; (1) The stations SKI and SMY show that the amplitudes of wave group around 5 to 10 seconds after the main S arrivals are as large as the main S wave. (2) The stations MRG and DIT shows not only the large amplitude of wave group around 15 to 20 seconds after S arrival but also the long period and long duration time. (3) The stations TIS, FKS and AMA also show the long period wave groups around 15 to 20 seconds after S arrival while the amplitudes are rather small. These characterized 3 station groups are located near the Uemachi fault, in the sedimental layers between the Uemachi fault and Ikoma Mountain, and in the soft soil layers in the Osaka bay areas, respectively.

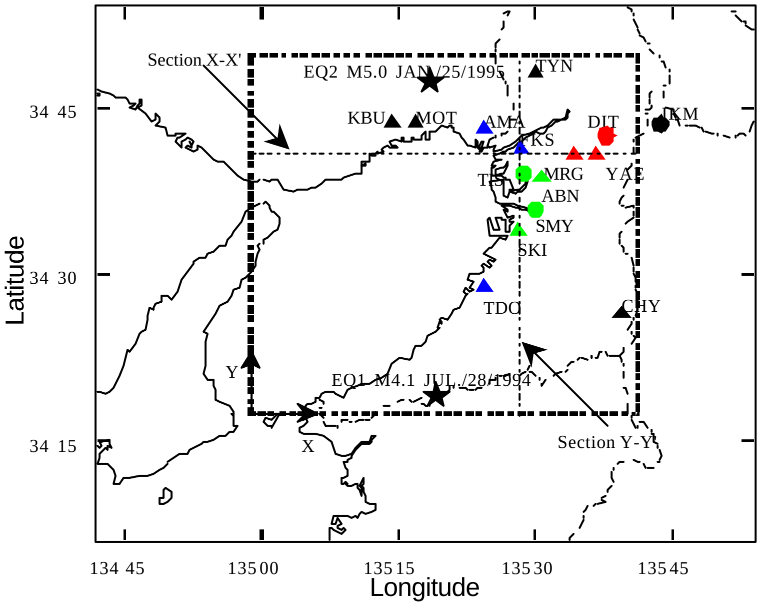
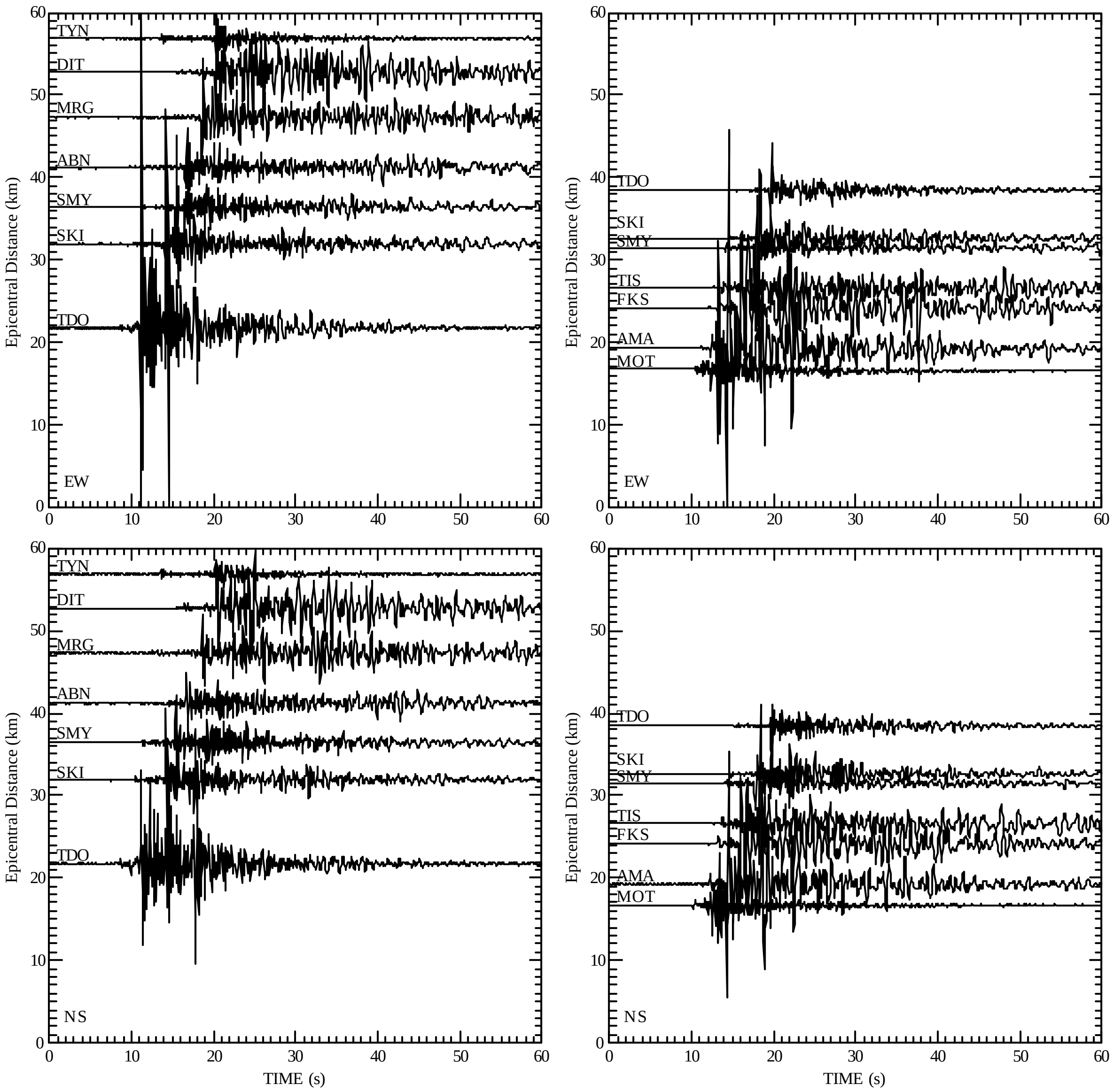


Figure 3: Observation Stations and Region of Modelling



(a)EQ1 occurred under the south part of Osaka Plain **(b)EQ2** occurred under the north part of Osaka Plain

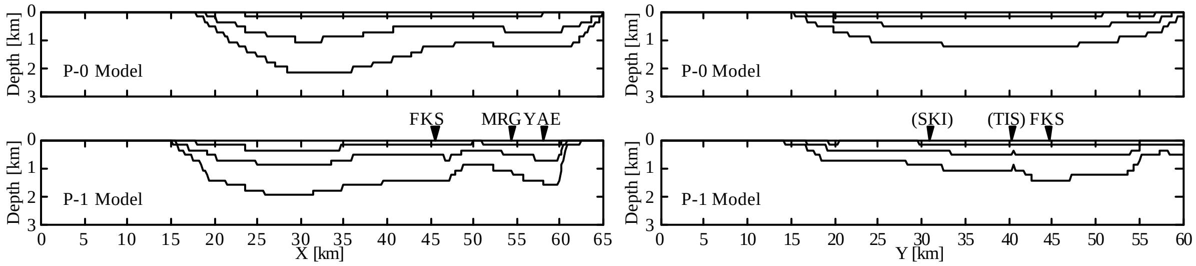
Figure 4: Observed Earthquake Records of EQ1 and EQ2

SIMULATION ANALYSES BY 3D FINITE DIFFERENCE METHOD

4.1 Analysis Model for 3D Finite Difference Method

Simulation analyses of ground motions using a fourth order staggered grid 3 dimensional finite difference method(Pitarka et al., 1996) were performed for the actual earthquakes. The analysis model of the Osaka plain represents an area 65km by 60km and a depth of 17km. The layer parameters used are the values shown in Table 1. The damping Q values(Graves, 1996) are determined from Vs[m/s]/10 at a reference frequency f_0=0.333 Hz.

The time increment and grid spacing for 3D finite difference analysis are 0.014 second and 175m, respectively so that the lower limit of period of calculation is 2.5 second at the layer of S wave velocity 350m/s. Total model dimension is about 12.5 million grid points. P-0 Model and P-1 Model are used in the 3D finite difference analyses. Figure 5 shows the east-west and north-south sections of P-0 and P-1 Models. P-1 Model can express the basin structure change better than P-0 Model.



(a) X-X' **(b) Y-Y'**

Figure 5: Cross Section

4.2 Source Model

The Japan Meteorological Agency(JMA) magnitudes of selected earthquakes were 4.1 and 5. One occurred under the north part, the other occurred under the south part of the Osaka plain.

A point source with a bell-typed source time function are used and source parameters are shown in Table 2. The rise time of source function is assumed to be 1 second. The source parameters were adopted from the source mechanism by JMA except the seismic moment. The seismic moment of EQ1 was decided as the amplitude of CHY located on a rock site was adjusted, and the seismic moment of EQ2 was selected as Matsushima et al.(1998) estimated the source parameters on EQ2.

Table 2: Source Parameters

Event	M_{JMA}	Longitude [deg.]	Latitude [deg.]	Strike [deg.]	Dip [deg.]	Slip [deg.]	Depth [km]	M_0 [N*m]
EQ1	4.1	135.318	34.318	348	30	111	9	$0.56*10^{15}$
EQ2	5.0	135.307	34.788	60	56	-169	15	$0.82*10^{16}$

4.3 Results and Discussions

Figure 6 shows the distributions of horizontal ground motion peak velocity at ground surface comparing observed and analysis results by P-0 and P-1 Model. According to the increase of thickness of sedimentary layer (see Figure 5), the maximum values become larger in both north-south and east-west component. The maximum values at the points X=60km of P-1 Model are larger than that of P-0 Model and vice versa at Y=55km, which are caused by the difference of the basin shape.

Figure 7 compares time histories of response velocity observed and simulated by FDM. All of the time histories for these comparisons have been filtered in the bandpass 2.5 < T < 10 second. The time delays of response results by FDM at every station coincide well with observed ones whereas the epicenters of selected earthquakes were quite different; the basic 3D sediment structure of the Osaka plain is appropriate. Analysis results show the short duration time and pulse wave at the point with shallow bedrock while the long duration time and long period phase were found at the central region in plain. These results correspond to the observed records.

The amplitudes, envelopes and phases of waveforms at AMA and SMY can be simulated quite well. Not only a waveform but also nonstationary spectra at AMA and SMY are well simulated as shown in Figure 8. The time change of predominant period, which means the wave is dispersed, is also similar with both observed and simulated results.

Based on the reflection survey(Horike et al.,1996), the basin shape of the Ikoma fault and the depth of sedimentary layers located at east/north part of the Osaka Plain are modified. However, the amplitudes at YAE and TYN do not coincide because the underground structure may be more complicated. A present model should be improved by detail investigations.

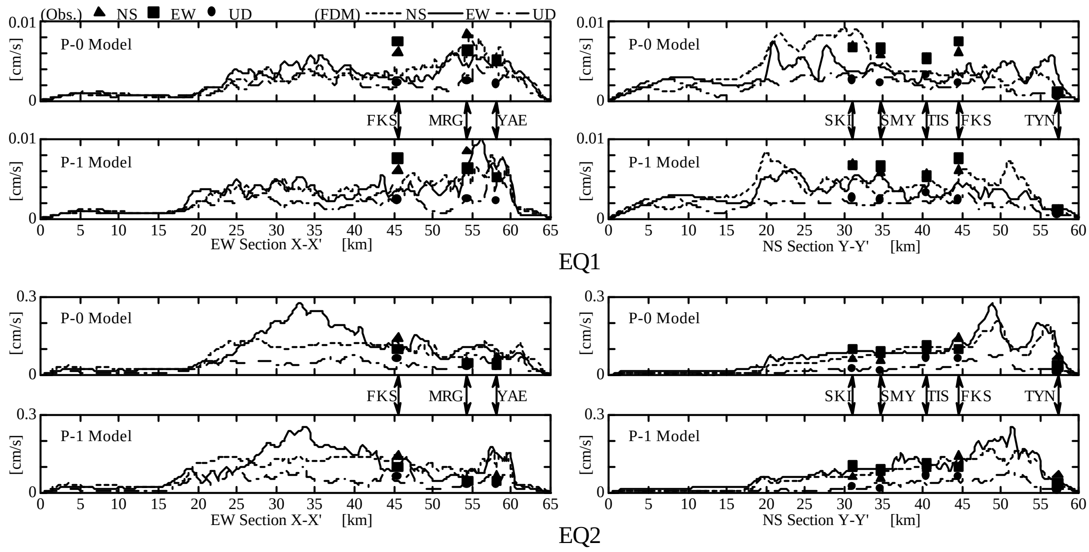


Figure 6: Distributions of Ground Motion Peak Velocity at Ground Surface

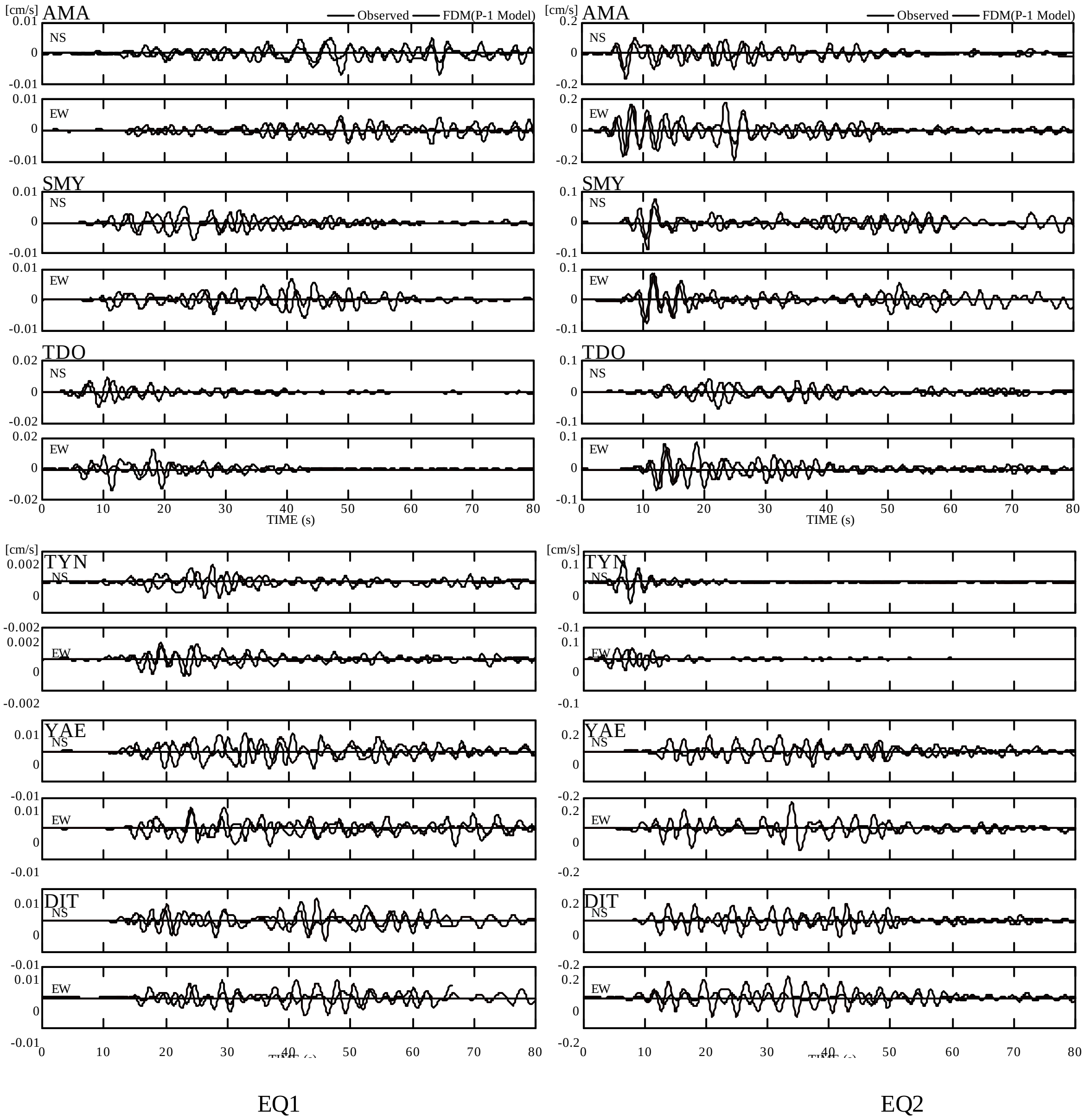


Figure 7: Comparison between Recorded and Calculated Ground Velocities

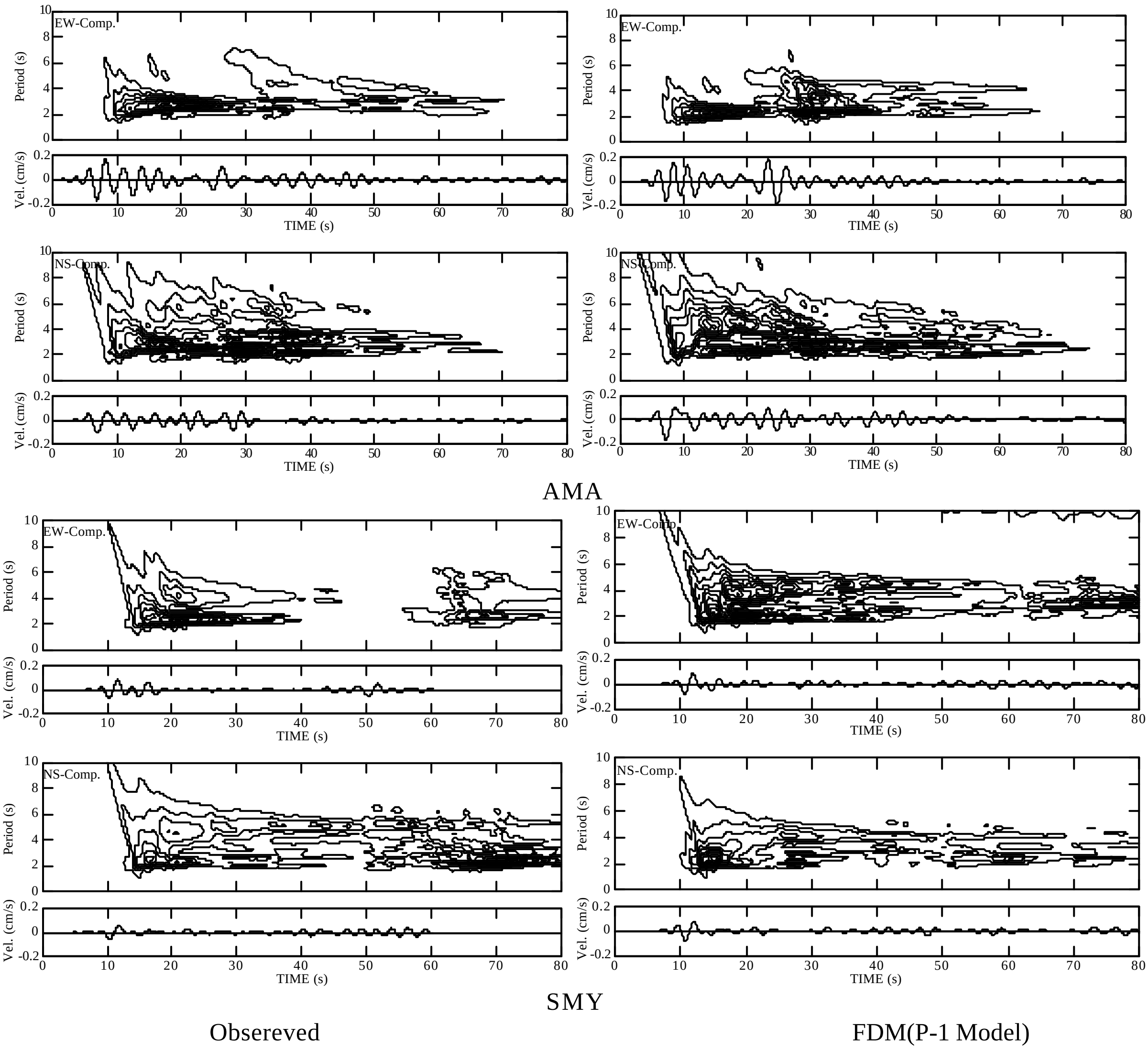


Figure 8: Nonstationary Spectra at AMA and SMY of EQ2

CONCLUSIONS

1. A deep sediment/basin structure model including Osaka and Kobe urban areas was constructed based on the various investigations and materials.

2. 3D FDM analyses almost gave the sufficient simulation of observation records. A present structure model was appropriate to evaluate the seismic response ground motions in perspective by simulation analyses using 3D FDM.

3. The amplitudes at the east/north part of the Osaka Plain did not coincide with the observed records because the underground structure may be more complicated.

4. A present deep sediment/basin structure model should be improved by accumulating soil profiles in an insufficient database so that the agreement at some stations with complicated sediment/basin structure would be well.

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