MICROZONING OF SEISMIC INTENSITY DISTRIBUTION CONSIDERING SITE EFFECTS DUE TO IRREGULARITY OF SUBSURFACE SOIL STRUCTURES

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SUMMARY

This paper describes the micro-zoning study for seismic intensity distribution considering the irregularities in geological underground conditions focussing on Nishinomiya-ctiy in Hyogo prefecture Japan. The soil structure of Nishinomiya-city is composed by the soft sedimentary subsurface layer covered on the slopping bedrock from north to south direction, and this region was suffered serious damages and recorded the highest degree in Japanese seismic intensity scale (I_{JMA}=7) in 1995 Hyogo-ken Nanbu Earthquake, Japan.

In this paper, we made 1-D and 2-D (two-dimensional) micro-zoning maps of seismic intensity distribution in Nishinomiya-city. The 1-D zoning map was made by soil response analysis with SHAKE program, and we used the SuperFLUSH/2D program which use 2-D finite element method, for the 2-D soil response analysis. We calculated the transfer function, maximum acceleration and velocity (PGV) values at the surface of ground, and we estimated the seismic intensity (I_{JMA}) from the result of PGV values using the empirical relationship between PGV values and I_{JMA}.

We compared the both results between 1-D and 2-D zoning map, and also compared between these maps and the evaluated seismic intensity distribution by JMA just after the 1995 Hyogo-ken Nanbu Earthquake. The results of comparison differ in 1-D and 2-D soil response analysis clearly, and 2-D zoning map provide a good agreement with the practical seismic intensity distribution.
These results show that it must to be considered the site effects influenced by irregularities of subsurface soil structures into the seismic micro-zoning and also seismic risk assessment studies.

INTRODUCTION

It is very important to estimate the distribution of seismic intensities for regional earthquake damages prediction about future big earthquake. The seismic intensity is strongly influenced by subsurface ground condition and basement irregular boundary condition. Although we usually estimate the site effect, predominant period and amplification, based on 1-D (one-dimensional) analysis method in order to predict the seismic intensity.

Attention is focused on Nishinomiya-city in Hyogo pref., Japan, and the present paper considers the micro-zoning study for seismic intensity. Nishinomiya-city was suffered serious damages and four areas of this city recorded the highest degree in Japanese seismic intensity scale (IJMA=7) in 1995 Hyogo-ken Nanbu Earthquake, Japan. We tried to make two micro zoning maps of seismic intensity distribution in Nishinomiya-city by 1-D and 2-D (two-dimensional) soil response analysis. We compared between these maps and the evaluated seismic intensity distribution by JMA just after the 1995 Hyogo-ken Nanbu Earthquake, and the rate of the razed wooden house

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OUTLINE OF NISHINOMIYA-CITY

The lay of the land

Nishinomiya-city is located to the east of Hyogo Pref. and spread to the gourd style with respect to the east and west of 13.8 km, the north and south of 19.1 km. The mountainous region where belongs to the Mount East Rokko system in the center of the city area is crossing in the east and west, and the south is facing in Osaka Bay with respect to 5.5 km. Therefore, the city area is the lay of the land that have the undulations that reach to the above sea level to 900 m of 0 m.

The surface of the mountainous region that belongs to the Mount East Rokko system of north is covered to the diluvial layer (the Osaka layer group, the terrace gravel layer) that consists of gravel, sand and clay. The city area of the south is formed on the delta of the alluvium layer that the plentiful earth and sand is carried to the lower stream by the weathering and erosion of granite and was able to accumulate.

In this paper, we tried micro zoning targeting the city area of this south.

Ground type

We classified the ground of Nishinomiya-city into 20 kinds in the light of the bowling pillar shape figures and also land condition figure etc. and set up representative ground structure model and N value every each ground type. We divided Nishinomiya-city into the mesh of about 500×500 m to do micro zoning, and we set up the standard ground model to each mesh. In the case that a plural ground type exists into one mesh we adopted the ground type that the center position of the mesh. The ground type that set up it every each mesh is shown in Figure 1.

Seismic intensity and razed house rate

The seismic intensity distribution in the Hyogo-ken Nanbu Earthquake that Meteorological Agency announced is shown in Figure 2. As for in Nishinomiya-city four areas were determined as seismic intensity 7 by Meteorological Agency. We obtained the damage data of the building of Nishinomiya-city and divided the city area for the mesh of 250×250 m and made the zoning map of the complete collapse rate of the wooden house. The zoning map that we made is shown in Figure 3. As for these figures, the high area of the complete collapse rate is showing that is almost corresponding to the area of seismic intensity 7 where Meteorological Agency announced. Also, we understand that the high area of the complete collapse rate is distributing with the form that went along the Koyo fault.

D MICRO ZONING

Method

We divided Nishinomiya-city into the mesh 500×500 m, to simulate the seismic intensity distribution of Nishinomiya-city by the Hyogo-ken Nanbu earthquake in 1995.

We supposed that the Rokko fault belt moved and calculated the maximum velocity values in the base of engineering every each mesh by the distance-damping expression. Next, we do one-dimensional earthquake response analysis every ground type and calculated the amplification rate of the subsurface ground. We calculated the maximum velocity in the ground surface by using maximum velocity value in the base of engineering and the amplification rate. Furthermore we transformed maximum velocity value into seismic intensity.

Maximum velocity

In this paper, we calculated the maximum velocity value in the rock of engineering by using the equation of Midorikawa (1993). We supposed that the Rokko fault belt that is located in the northwest of the city area moved and calculated maximum velocity value. The Rokko dislocation belt that set up it depends to Matsuda (1990) and shown the each source in Table 1. We did calculation in the center position of each mesh. The focus distance from the calculation point to fault plane is about 18 21 km. The distance from the fault becomes long as the south of the city area, because it is using the distance-damping equation and maximum velocity in the rock becomes small. The maximum velocity value in the rock of the engineering that calculated it is about 52 58kine.

Amplification rate

We carried out the earthquake response analysis individually to 20 kinds of ground models that set up it with this study and calculated the amplification rate of the surface ground. The amplification rate calculated by the ratio between the peak velocity response value in the surface of ground and maximum velocity value in the rock of engineering. The input seismic wave that we used to calculation is shown in Figure 4. This input motion is the wave on the rock of the engineering that the author calculated in the SS session of ESG1998. (The details were referred to the proceeding of ESG 1998). The amplification rate that calculated it is shown in Figure 5. The amplification rate of the city area that calculated it is about 1.2~2.5. This figure is showing that the amplification rate is high in the area which faced in Osaka Bay of the south.

Seismic intensity

By multiplying the amplification rate that aforementioned it to the maximum velocity value in the rock of engineering we calculated the peak velocity value in the ground surface. The maximum velocity in the ground surface of the city area is about 70~130kine and the peak velocity is strong in the high mesh of the amplification rate. We transformed maximum velocity into seismic intensity by using the equation of the Huanan Tang, etc. (1996). Last we set up the seismic intensity class, from the correspondence table between the seismic intensity class and seismic intensity that show in Table 2. The distribution of the seismic intensity class that we calculated in this way is shown in Figure 6. The figure is showing what seismic intensity 7 is distributing in the coast area. We compared the zoning map and area of seismic intensity 7 of Meteorological Agency and complete collapse rate. Especially, the northeast area of the city is evaluated small.

2-D MICRO ZONING

We set up two-dimensional model to consider the irregularity of soil structures and did the earthquake response analysis. From the result we revise the amplification rate of the surface ground and tried micro zoning.

Two-dimensional model

The city area of Nishinomiya-city makes Mount Kabuto the back and spread toward the southwest. In this paper, we set up the representative section of the city area of Nishinomiya-city. Two-dimensional model and material of soil are shown in Figure 7 and Table 3. The range of A~B of figure 7 is showing the mountainous region, the range of B~C is the plateau, C~D is showing the plain of the city area. The plain of C~D made the model that a soft layer accumulated 20 m. We did the earthquake response analysis by using program SuperFLUSH/2D which use two-dimensional finite element method. We calculated the maximum acceleration value and amplification rate in the ground surface. The input ground motion that we used to the analysis made the same wave with original that we used with SHAKE. The input motion prescribed to the rock position of the engineering (GL -20m) in the free field.

Calculation result

The distribution of the maximum acceleration in the ground surface is shown in Figure 8. We understand that the maximum acceleration value in a softer ground (the range of C~D) is high from Figure 8. The amplification rate in the range of C~D is about 1.5~2.0 times compared with the result of one-dimensional analysis. It is said well to general, that the seismic wave amplifies it in the boundary neighborhood of a hard rock and soft soil, like this. In this case, the range where this response becomes high is the range of about 1.5~2.5 km from the B point of the figure 7. Therefore, we made to revise the amplification rate of the plain of plateau neighborhood on the basis of the analysis result. The amplification rate that we revised is shown in Figure 9.

Micro zoning map

The seismic intensity in the surface of the ground was calculated, by using the amplification rate that we revised. The result that calculated it is shown in Figure 10. It is shown in Figure 10 that the mesh that was calculated with seismic intensity 7 and also a little over 6 seismic intensity are increasing in comparison with the result of one-dimensional approach. Especially, the area of seismic intensity 7 spreads in northeast from southwest. This micro zoning map is able to take the distribution and comparatively good correspondence of seismic intensity 7 of Meteorological Agency. Also, we compared the distribution of the complete collapse rate of wooden house and this zoning map. As a result, both are showing comparatively good correspondence.

CONCLUSION

First we calculated the complete collapse rate of the wooden house, by using the damage data of the building that was offered from Nishinomiya-city. As a result, we were able to confirm that the complete collapse rate is high in the area of seismic intensity 7 of Meteorological Agency announcement.

Next, we did the micro zoning of the seismic intensity in Nishinomiya-city by the method from formerly. As a result, the distribution of seismic intensity 7 was seen in the area of the soft foundation on the side of the sea. However, the area of seismic intensity 7 of Meteorological Agency announcement was unable to be simulated.

Last, we tried earthquake answer calculation by two-dimensional model, to consider the irregularity of the soil structures. On the basis of the result of two-dimensional analyses, we set up the amplification rate and did micro zoning. As a result, the micro zoning maps by two-dimensional approach was able to explain the complete collapse rate and seismic intensity distribution in Hyogo-ken Nanbu Earthquake (1995).

These results showed that it must to be considered the site effects influenced by irregularities of soil structures into the seismic micro zoning and also seisimic risk assessment studies.

ACKNOWLEDGMENTS

We asked the ground classification of Nishinomiya-city of Dr. Matsuda of Kanto Gakuin University. The authors are very grateful to Dr. Matsuda. We thank for Nishinomiya-city where offered the building damage data of Nishinomiya-city. We thank for Mr. Ochiai of Kanagawa University graduate school master course who took the trouble of helping data tidying and two-dimensional analyses.

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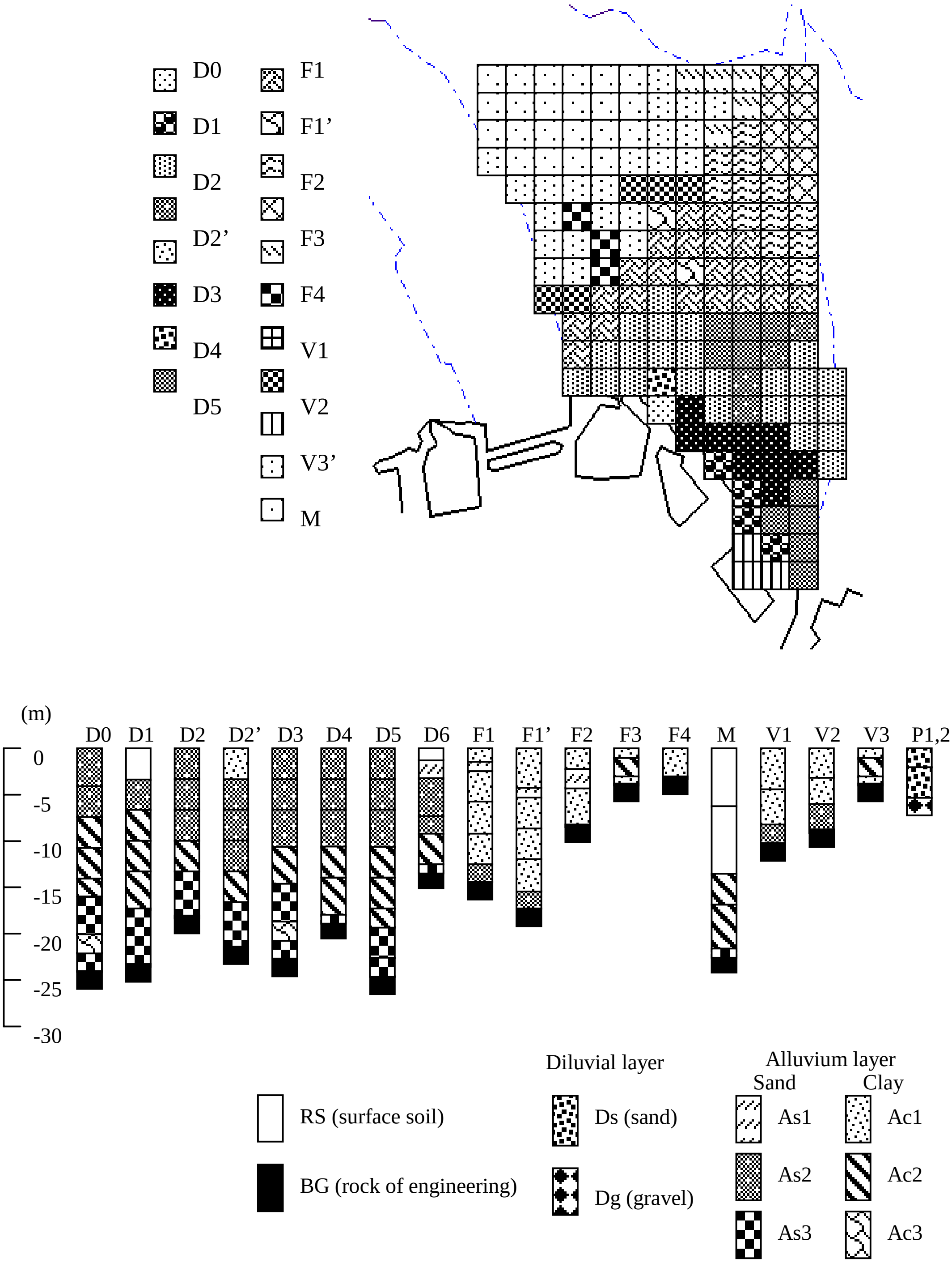

Figure 1 Ground type and soil structure model

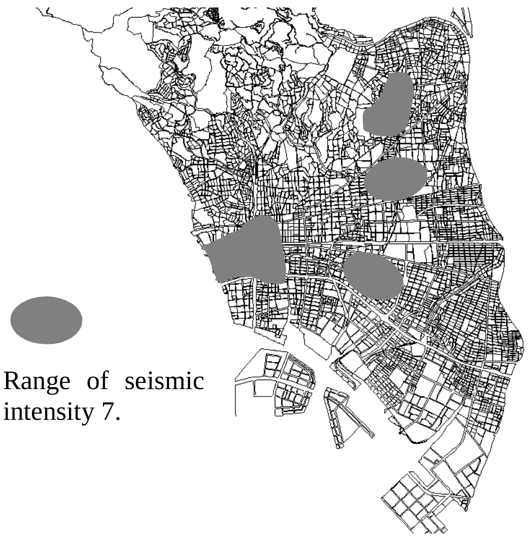

Figure 2 Range of seismic intensity 7.

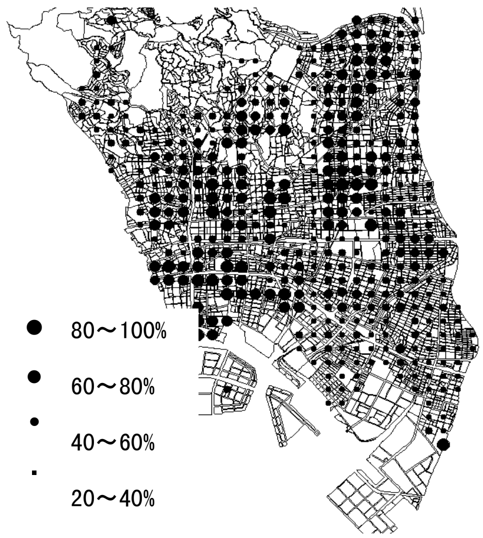

Figure 3 Rate of the razed wooden

Table Source of Rokko fault belt

Dislocation Length (km)	Earthquake scale (ML)	Focus depth (km)
47.00	7.60	17.69

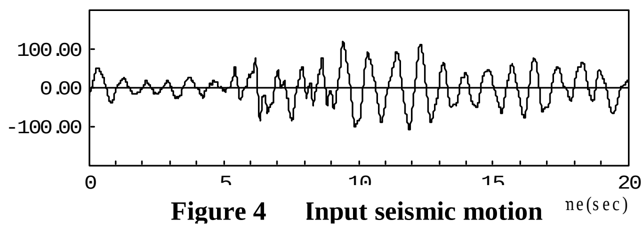

Figure 4 Input seismic motion

Table 2 Correspondence of calculation seismic intensity and seismic intensity class.

Calculation seismic intensity	3.5	4.5	5.0	5.5	6.0	6.5
Seismic intensity class	4	below 5	over 5	below 6	over 6	7

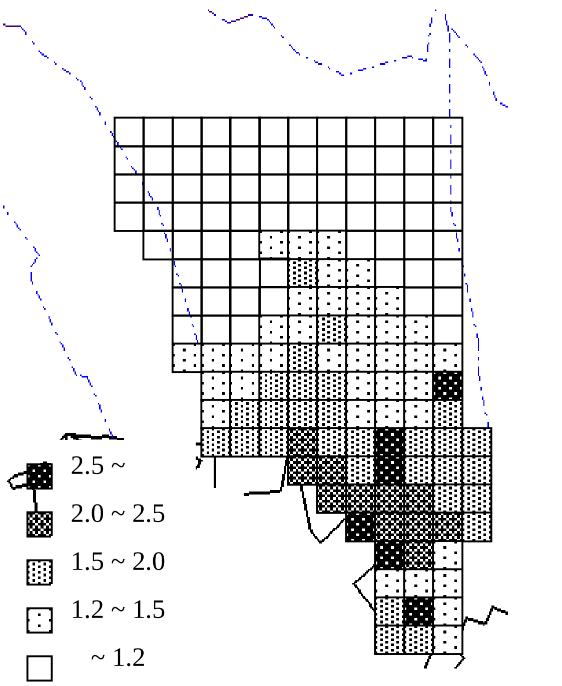

Figure 5 Amplification rate. (1-D approach)

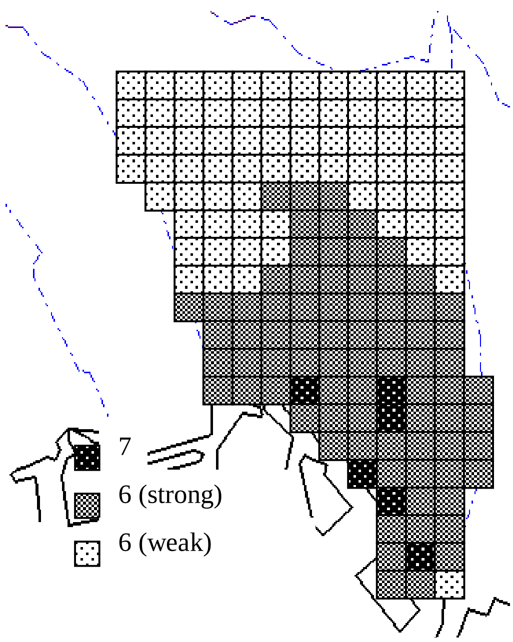

Figure 6 Zoning map of seismic intensity. (1-D approach)

Table 3 Material of 2-D soil structure model.

Layer	γ	Vp (m/s)	Vs (m/s)
1	1.6	1000	150
2	1.6	1500	320
3	1.8	1700	500
4	1.9	1800	650
5	2.1	2500	1000
6	2.5	5000	2500

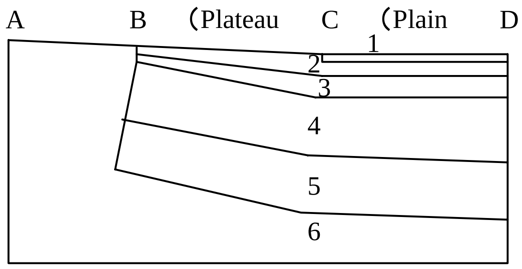

Figure 7 2-D soil structure model

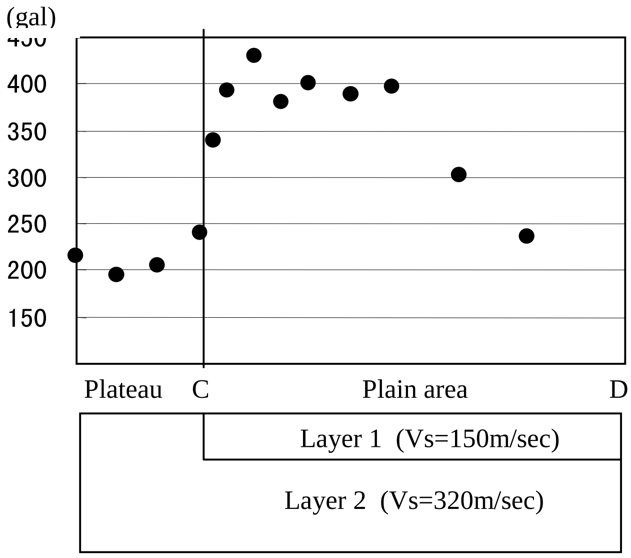

Figure 8 Maximum acceleration in the ground surfaces by 2-D analysis.

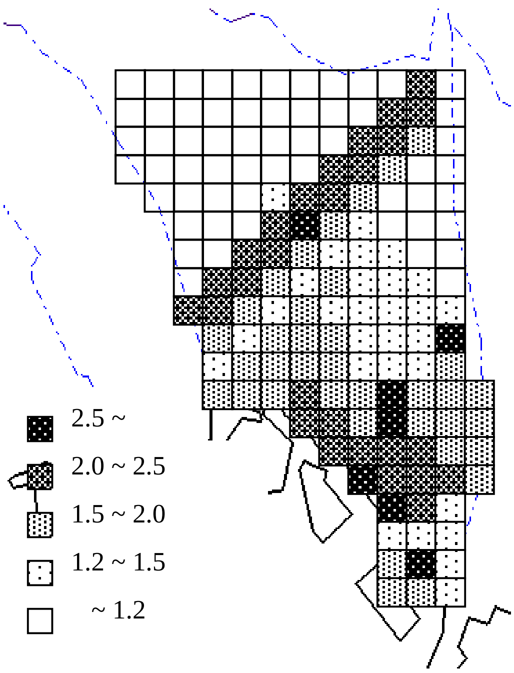

Figure 9 Amplification rate after revision.(2-D approach)

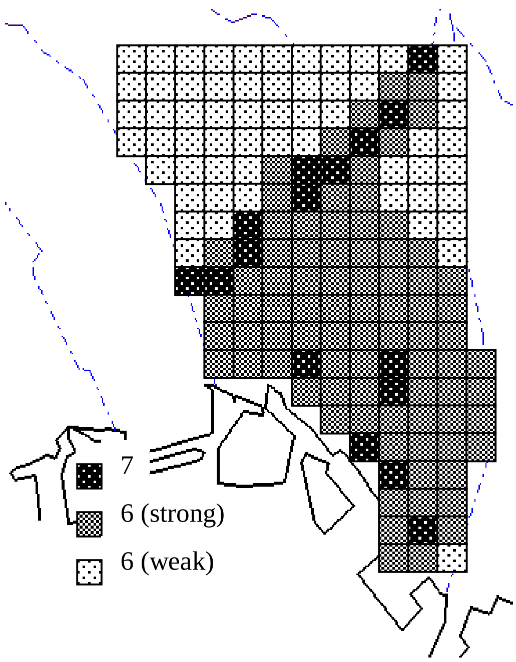

Figure 10 Zoning map of seismic intensity. (2-D approach)