Earthquake Engineering, Tenth World Conference © *1992 Balkema, Rotterdam. ISBN 90 5410 060 5*

Site effects evaluated by detailed seismic intensity, peak acceleration and velocity, ground vibration by aftershock and microtremor, surface geology, and theoretical amplification on the ground in Akita City, Japan

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ABSTRACT: Since the 1983 Nihonkai Chubu earthquake of magnitude 7.7 occurred in the Japan Sea about 100 km west of Noshiro City, Akita Prefecture, Japan, many investigations and studies on seismic microzonaion were made in Akita City, Noshiro City and Honjo City, Akita Préfecture, Japan First, we obtained the detailed seismic intensity at subarea of about 250m x 250m throughout Akita City. Second, we analysed the strong-motion accelerograms of 54 components on the 1983 Nihonkai Chubu earthquake, and obtained some attenuation curves of peak acceleration and velocity in northern Tohoku district, Japan. Third, we investigated about the ground vibration by the aftershock and microtremor measurements with S-wave velocities on the ground surface in Akita City. Forth, we used microtopographical maps of Akita City. Fifth, by using many boring data, we calculated the amplification of the ground motion at each subarea of about 250m mesh in Akita City by means of the multiple reflection theory of SH wave.

In this paper, we tried to overlay and evaluate totally such terms on seismic microzonation as the detailed seismic intensity, peak acceleration and velocity, microtopopraphy and subsurface geology, ground vibration by after shock and microtremor, and theoretical amplification on the ground at subarea of 250m mesh in Akita City. We calculated the principal components between these terms, by means of the principal component analysis, and discussed the site effects which were evaluated by the principal components.

1 INTRODUCTION

The 1983 Nihonkai Chubu earthquake of magnitude 7.7 occurred in the Japan Sea about 100km west of Noshiro city, Akita Prefecture, Japan, and many investigations and studies on seismic microzonation were made in Akita City, Noshiro City and Honjo City, Akita Prefeture, Japan.

First, we obtained the detailed seismic intensity at subarea of 250m x 250m throughout Akita City and Noshiro City, and about 1km x 1km throughout Akita Prefecture, by means of the questionnaire mehtod of Ohta, et al. (1978) [Nogoshi, 1988].

Second, we analysed the strong-motion accelerograms of 54 components on the 1983 Nihonkai Chubu earthquake, and obtained some attenuation curves of peak acceleration and velocity in northern Tohoku district, Japan [Nogoshi and Nakamura, 1989a, 1989b and 1990].

Third, we investigated about the ground vibration by the aftershocks and microtremors measurements in Akita, and Noshiro Cities [Nogoshi, 1985].

Forth, we used microtopographical maps of Akita City and Noshiro City, which were investigated and drafted by a geological research group of Akita University (1986).

Fifth, by using many boring data, we calculated the amplification of the ground motion at each subarea of about 250m mesh in Akita City, by means of the multiple reflection theory of SH wave. After we investigated these terms on seismic microzonation of the ground, first we perfomed statistical evaluation between site effect of geological conditions and detailed seismic intensities [Nogoshi, 1989], and made an empirical formula for estimating the detailed seismic intensity by means of multiple regression analysis [Nogoshi, 1990]. The equation of detailed seismic intensity consisted of Kawasumi's equation (1951), microtopography, subsurface geology and depth to diluvium or tertiary in Akita and Noshiro Cities. Second, we discussed relations between the detailed seismic intensity and the peak accelerations and velocities in Akita Prefecture and Tohoku district. Third, we researched into microtremor characteristics at area in Akita City and Noshiro City, damaged Noshiro City and Akita City, which damaged by soil liquefaction during the 1983 Nihonkai Chubu earthquake [Nogoshi, et al. 1987].

In this paper, we tried to overlay and evaluate totally such terms on seismic microzonation as the detailed seismic intensity, peak acceleration and velocity, microtopography and subsurface geology, ground vibration by aftershock and microtremor, and theoretical amplification on the ground at subarea of 250m mesh in Akita City.

2 INVESTIGATION TERM

Akita City,Noshiro City and Honjo City in Akita Prefecture,northern Japan are shown in Figure 1[Nakamura,et al.,1989]. Our investigations on seismic microzonation of the ground were made in these cities for 1984-1990. However,we described only on Akita City in here. After the 1983 Nihonkai Chubu earthquake occurred,the microtpography and subsurface in Akita City and Noshiro City were investigated by Kotoda and Wakamatsu(1984) and Geological Research Group of Akita University(1986). In Figure 2,we showed the microtopographical map [Kotoda and Wakamatsu,1984] with areas liquefied by the 1983 Nihonkai Chubu earthquake. We used as mesh data which were divided the microtopographical and subsurface geology data into each subarea of about 250m x 250m throughout Akita City,in order to compare with other investigation terms.

Next,the detailed seismic intensities were shown in Figure 3,as a part of distribution at subarea of 250m x 250m throughout Akita City. The Numbers are represented at ten times as many as the detailed seismic intensity. The detailed seismic intensity were calculated by a questionnire method of Ohta, et al.,immediately after the 1983 Nihonkai Chubu earthquake occuured. Already,the detailed seismic intensities were compared statistically with geological sites at subarea of 250m x 250m in Akita City,and this comparison were made on Noshiro City and throughout Akita Prefecture [Nogoshi,1989]. As the results,the detailed seismic intensities were corresponded very

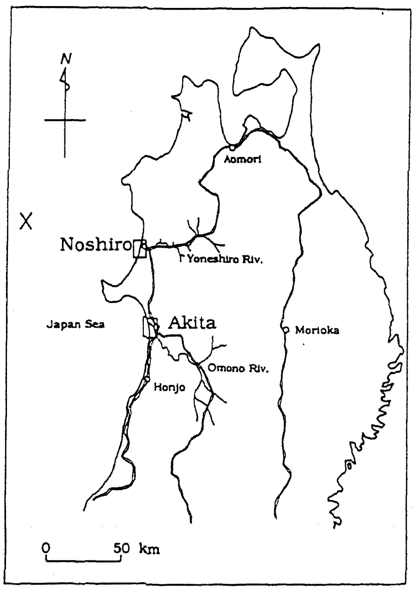


Figure 1. Locations of Akita City,Noshiro City and Honjo City in Akita Prefeture, northern Japan.(After Nakamura et al.,1989)

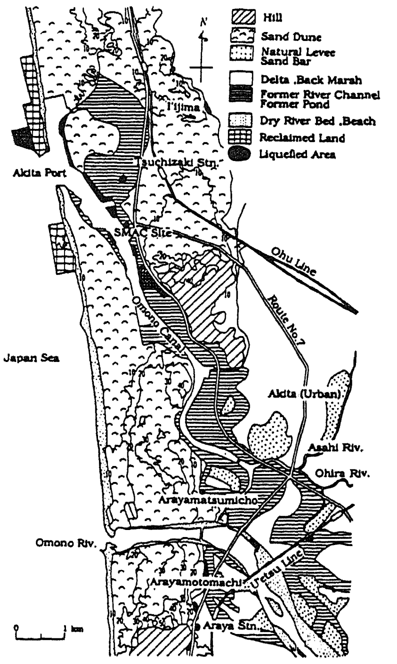


Figure 2. Subsurface and microtopographical map in Akita City.with the areas liquefied by the 1983 Nihonkai Chubu earthquake. (After Nakamura et al.,1989)

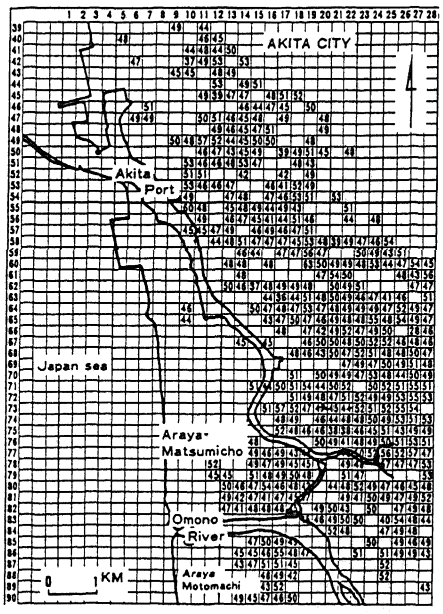


Figure 3. A part of distribution of detailed seismic intensity at subarea of 250m x 250m throughout Akita City. The numbers are represented at ten times as many as the detailed seismic intensity.

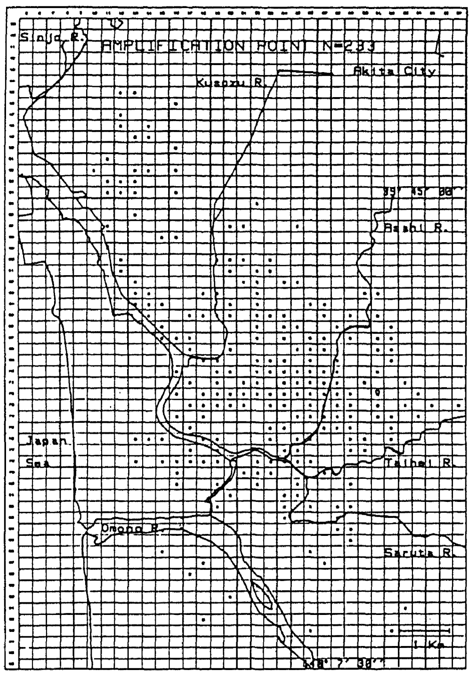


Figure 4. Locations(*) of boring data at subarea of 250m x 250m throuout Akita City.

well to classification of soft and hard microtopography and ground surface geology in Akita City. It was found that the accuracy of the detailed seismic intensity was 0.1-0.2 from standard error calculation. Moereover, we made an empirical formula for estimating the detailed seismic intensity by means of multiple regression analysis[Nogoshi,1990].

In Figure 4,locations of boring data at subarea of 250m mesh throughout Akita City. 580 boring data were obtained in Akita City,but we obtained 233 boring data,after we selected as the deepest boring datum of some boring data at each subarea of 250m mesh in Akita City. Thickness to tertiary,depth to N-value=50 and depth which N-value changed steeply were obtained as three informations from 233 boring data.

Next,we analysed the strong-motion accelerograms of 54 components on the 1983 Nihonkai Chubu earthquake,and obtained some attenuation curves of peak acceleration and velocity in nothern Tohoku district and Akita Prefecture [Nogoshi and Nakamura,1989]. Peak acceleration and velocity at subaea of 250m mesh were calculated from the attenuation curves of Akita Prefecture.

We investigated about the ground vibration by the aftershocks of the 1983 Nihonkai Chubu earthquake and microtrmor measurements with S-wave velocities on the ground surface in Akita, Noshiro and Honjo Cities[Nogoshi,,1985;Reserch Group of Short- and Long-Microtremors,Nogoshi, et al.,1987].

Short-period microtremor characterization was investigated in detail at damaged regions in Noshiro City and Akita City,where damaged by soil liquefaction during the 1983 Nihonkai Chubu earthquake.We found out that the distinctive spectral types were obtained in sites damaged by liquefaction, from results of spectral studies of the short-period microtremors. Predominant period and peak velocity amplitude of the short-period microtremors were calculated at each subarea of 250m mesh in Akita City.

By using 580 boring data and S-wave velocities,we calculated the amplification of the ground motion in the boring sites,while we computed some empirical equations estimating S-wave velocities in Akita City. Moreover,the theoretical amplification of the ground motion at each subarea of 250m mesh were computed by means of the multiple reflection theory of SH wave(Figure 4). S-wave velocities on the ground surface in Noshiro,Akita and Honjo Cities were measured by method hitting a plate,with researching into undergroud water level,and related to liquefied sites[Research Group of Short- and Long-Period Microtremors,Saito,et al. ,1988].
a and 1988b

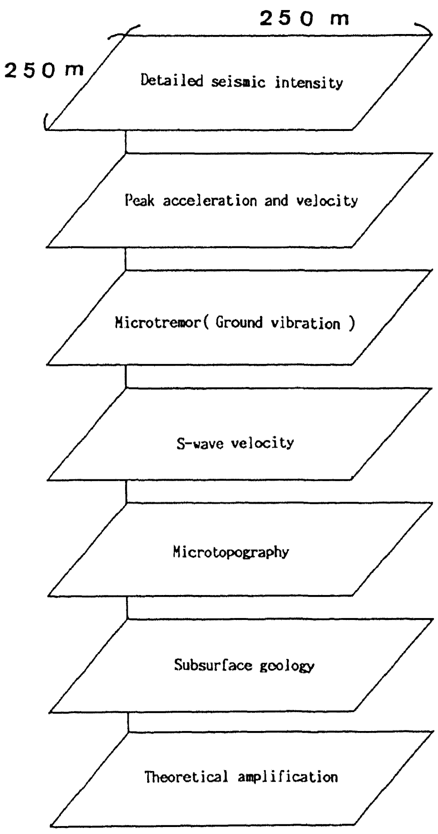


Figure 5. Overlay model of term data of 250m mesh data.

Also,we researched into the underground water level from boring data in Akita City and Noshiro City.

Moreover,we used the damage investigation data(total collapse and half collapse) in Akita City during the 1983 Nihonkai Chubu Earthquake.

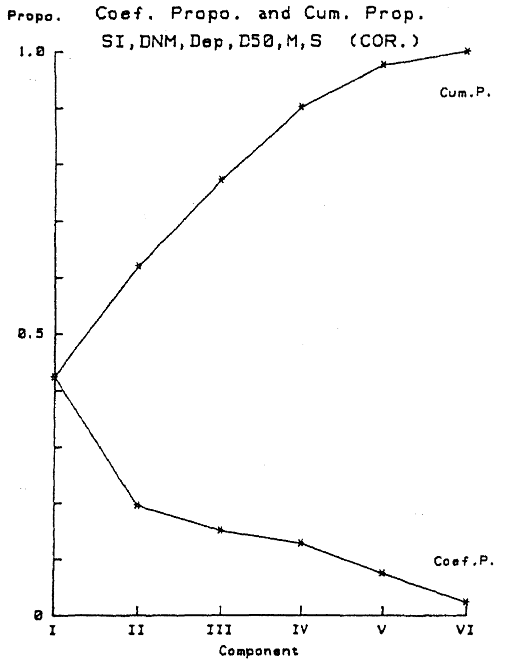


Figure 6. C.P. and P. of principal components.

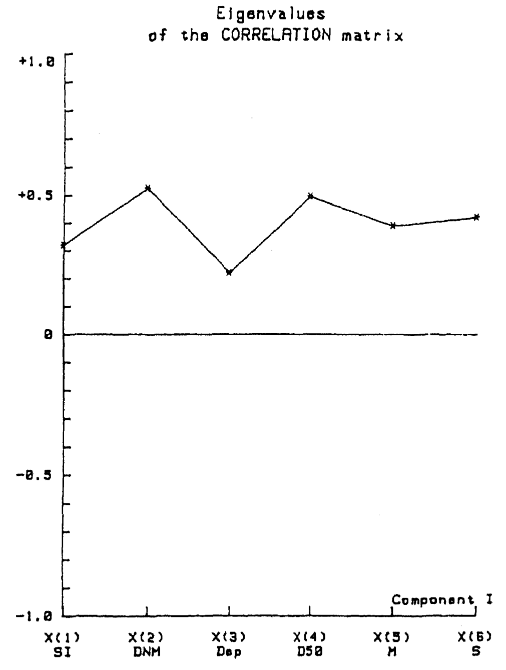


Figure 7. Eigenvalues(Component I) of 6 variables.

3 SITE EFFECT EVALUATION OF OVERLAY METHOD

We tried to use the pricipal component analysis as a method to evaluate the site effects,that is,we tried overlay and evaluate totally such terms on seismic microzonation as the detailed seismic intensity,boring data(depth to tertiary ,etc.),microtopography and subsurface geology, theoretical amplification on the ground,ground vibration by aftershocks and microtremors measurements,peak acceleration and velocity, S-wave velocity on the groud surface,undergroundwater level,and damage investigation data at subarea of 250m mesh in Akita City.

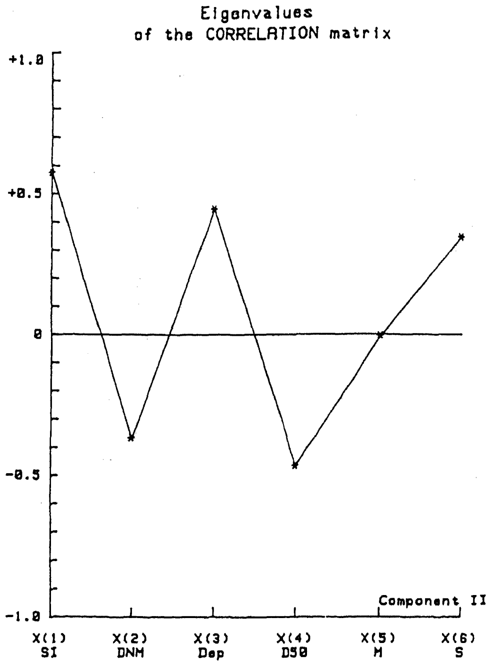


Figure 8. Eigenvalues(Component II) of 6 variables.

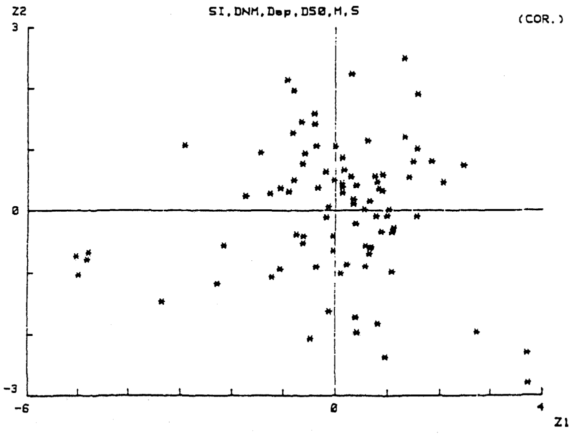


Figure 9. Scatter diagram of z_1 and z_2 .

We showed an overlay model of such term data of 250m mesh data as the detailed seismic intensity,etc.in Figure 5. We calculated the principal components between these terms,by means of the principal component analysis,and discussed the site effects which were evaluated by the principal components.

First,we calculated the principal components of the detailed seismic intensities(SI),boring data(depth which N-value changed steeply;DNM, thickness to tertiary;Dep,depth to N-value=50; D_{50}),microtopography(M),subsurface geology(S). As shown in Figure 6,7 and 8,we can see that approximately,2 principal components(I and II) explain totally these term data from cumulative proportion(C.P.),and component I shows only plus eigenvalue,and coponent II shows plus eigenvalues of SI,Dep,S and M. This result explains that the detailed seismic intensity is closely related the depth to tertiary,the subsurface geology and the microtopography.

Figure 9 shows a scatter diagram of scores(z_1) of component I and scores(z_2)of component II,and this explains that the used data at subaea of mesh is equally scattered.

Second,we calculated the principal components of the detailed seismic intensity(SI),the boring data(DNM,Dep and D_{50}),the microtopography(M) and the subsurface geology(S),the Amplification (peak amplification;BYB,predominant period;BX',and BYB x BX'),the damage invevstigation data(total collapse;C,half collapse;H). As shown in Figure 10,11,12,and 13,we can see that approximately,3 components(I,II, and III) explain totally these term data(11 variables) from cumulative proprtion(C.P.),and component I shows only plus eigenvalues except C and H,and component II shows plus eigenvalues except BX' and BYB x BX',and component III shows lager plus eigenvalues of C and H. Component I almost is similar to the first case,Conponent II and III are complicated,but it is estimated that the detailed seismic intensity(SI) is closely related the depth to tertiary(Dep),the microtopography(M),and the damage investigation data (C and H). Figure 14 shows a scatter diagram of scores(z_1) of component I and scores(z_2) of component I,and Figure 15 shows a scatter diagram of scores(z_1) of component I and scores(z_3) of component III,with the mark locations of damage investigation data(C and H). As shown in Figure 14, toatal collapse(C)

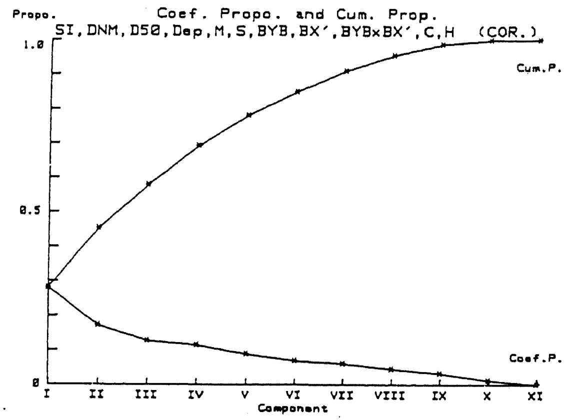
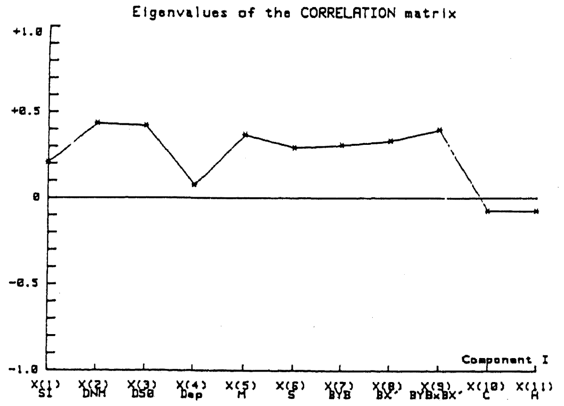


Figure 10. C.P. and P. of principal components.



Fugure 11. Eigenvalues(Component I) of 11 variables.

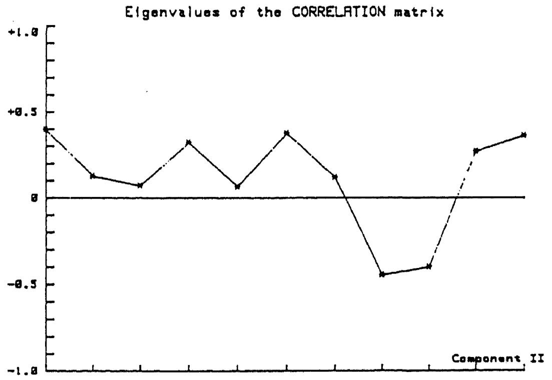


Figure 12. Eigenvalues(Component II) of 11 variables.

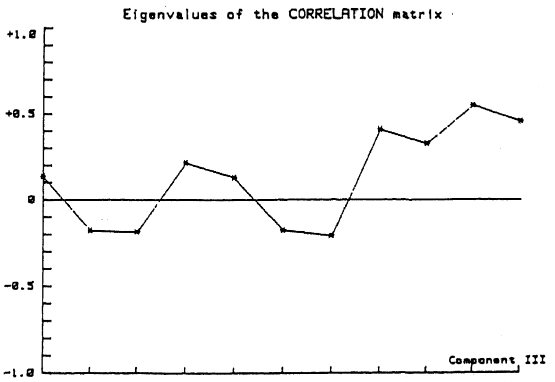


Figure 13. Eigenvalues(Component III) of 11 variables.

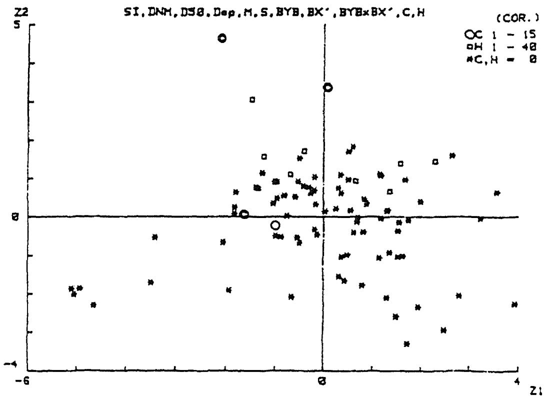


Figure 14. Scatter diagram of z_1 and z_2.

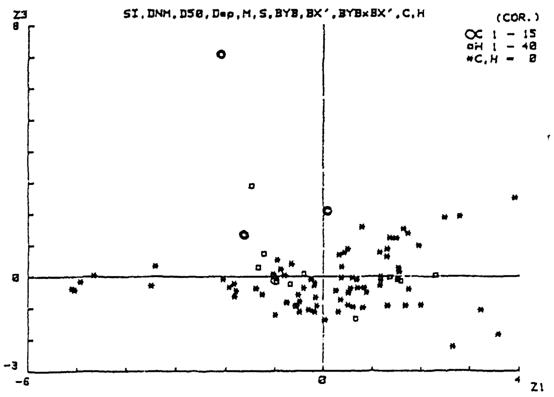


Figure 15. Scatter diagram of z_1 and z_3.

and half collapse(H) are closely related to the detailed seismic intensity(SI),the depth to tertiary(Dep),the subsurface geology(S) and the microtopograohy(M). As shown in Figure 15 and 13,total collapse(C) is approximately similar to the scatter diagram of z_1 and z_2. Moreover, we will report about the principal component as total term of seismic microzonation in future ,in addition to other term data,for example,the ground vibration, and peak acceleration etc.

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