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Development of database system supporting earthquake disaster mitigation programs for urban areas

H. Matsuzawa & M. Sugimura
Nagoya University, Japan

H. Taniguchi
CENAPRED, Mexico

ABSTRACT: The authors are constructing the aiding system for seismic disaster mitigation for the purpose of supplying the fundamental informations for mitigation planning in urban area. By using this system, unified management of various informations of urban environments and many-sided and rapid application of the informations can be carried out. This system was applied to case studies of estimations of liquefaction potential and damages of wooden houses in Nagoya city, Japan.

1 INTRODUCTION

Mitigation plan for seismic disaster in urban area should, all the time, be corresponding to the changes of urban environment and characteristics of earthquake disaster. In order to carry out the mitigation intentionally, planning for seismic disaster prevention and for urgent countermeasures will be indispensable. The former includes the plan for development of a city and prior countermeasures against earthquakes and the latter includes urgent restoration, rescue and refuge. Predictions of seismic damages of facilities and human beings within and around the city are fundamental informations for these plans.

Seismic disaster is complicatedly affected by characteristics of an earthquake, natural, artificial and social environments of the city and psychological effects of people. Then, various damages and confusion will be simultaneously induced under these environments. It is, therefore, very important to investigate the mechanism of damage and confusion occurrence due to past destructive earthquakes. And seismic disaster should be predicted based on these investigations and new knowledges about seismic disaster. These investigations and predictions mentioned above should be carried out from the view point of the natural science, social science and the humanities.

In order to draft the mitigation plan, it is necessary to collect many kinds of informations about the present and future city environments and to predict seismic damages. The predictions of seismic motion, geotechnical hazard and material and human damages due to the seismic motion will be indispensable for drafting the mitigation plan. It is also necessary to improve the strategy for urgent countermeasures, e.g. restorations of damaged institutions, rescue and refuge.

As mentioned at the beginning, the mitigation plan for seismic disaster should be corresponding to the changes of urban environments. It will be required that many environmental informations will be managed unifiedly and be applied many-sidedly and rapidly. In order to realize these requests, the computer system for the management and application of the informations will be most suitable.

The purposes of this study are the prediction of seismic disaster, including from the generation of seismic motion and outbreak of damages, and the supply of the fundamental informations for planning of mitigation. For these purposes, the authors are constructing the aiding system for seismic disaster mitigation planning. The system consists of database systems for various environmental informations and application systems which predict the seismic disasters and supply the basic informations against mitigation.

The authors developed the aiding system for investigating assumed earthquakes and the aiding system for estimation of seismic damages. In this paper, the outlines of the aiding system for seismic disaster mitigation planning will be shown, and will be applied to the estimation of liquefaction and damages of wooden houses in Nagoya city, Japan.

2 OUTLINE OF AIDING SYSTEM FOR SEISMIC DISASTER MITIGATION PLANNING

The aiding system for seismic disaster mitigation planning consists of three aiding systems as shown in Fig.1, i.e. the aiding

	Database	Systems for reference and analysis
Aiding system for investigating assumed earthquakes	**1. Info. of Earthquakes** Epicenter, Hypocenter Magnitude, Breakout time and etc.	**1. Analysis of seismic action** Distributions of hypocenter and epicenter Analysis of occurence frequency **2. Analysis of expectational seismic motion** Expectation of acc. (50~100year) Expectation of vel. (50~100year)
Aiding system for estimation of seismic damages	**1. Info. of natural environment** Maps, Surface geology Geomorphology Soil boring logs Soil tests and etc. **2. Info. of artificial env.** Underground lifelines and structures Number of houses and buildings and etc. **3. Info. of social environment** Population and etc. **4. Info. of disasters due to previous earthquakes**	**1. References** Geological and geotechnical database system and etc. **2. Analysis of seismic response** Estimation of S-wave velocity S-wave multiple reflecting response analysis Responce analysis by SHAKE **3. Liquefaction potential analysis** **4. Damage Estimations** Risk analysis of lifelines Damage of wooden houses Analysis of spreading fire and etc. **5. Elucidating analysis of disaster occurence**
Aiding system for countermeasure	**1. Codes for earthquake proof** **2. Disaster mitigation plan** **3. Urgent commodities** Food, Drinking water Materials for urgent restoration **4. Urgent staff**	**1. Aiding system for urgent countermesure** Systems for restoration strategy (PERT theory, etc.) **2. Aiding system for planning of seismic damage prevention** Investigation of predictional results

Fig.1 Composition of the aiding system for seismic disaster mitigation planning

system for investigating assumed earthquakes, the aiding system for estimation of seismic damages and the aiding system for countermeasure. The basic informations of this system are about earthquake environment, natural, artificial and social environment, damage information due to post earthquakes, codes for earthquake proof, urgent commodities etc., and these informations are managed on the system.

In the whole system shown in Fig.1, the aiding system for investigating assumed earthquakes has already been constructed. And systems for geological and geotechnical database, for seismic response analysis and for predictions of liquefaction, damage of wooden houses and human damages in aiding system for estimation of seismic damages have also been constructed. Summary of these systems will be shown in the following.

2.1 Aiding system for investigating assumed earthquakes

The basic informations for selection of assumed earthquakes are outbreak times, magnitudes and epicenters of earthquakes.

This system mainly consists of two subsystems, i.e. for the analysis of seismicity and for the analysis of expected seismic motion at seismic bedrock. By using the former, distributions of epicenters, magnitudes and occurrence frequency of earthquakes can be referred. And by the latter, expected maximum acceleration and velocity on upper surface of seismic bedrock at arbitrary region for future 50-100 years can be calculated under the given outbreak area, magnitude and outbreak time of earthquakes. In this calculations, accelerations and velocities are estimated by using the equations proposed by Okamoto (1966) and Kanai(1969), respectively.

2.2 Geological and geotechnical database system

The informations of ground are one of the important informations about natural environments, and will be utilized not only for mitigation of seismic disaster but also for planning of construction and land development and etc.

The basic informations of this system are about ground surface, e.g. maps, surface geology, geomorphology, and about subground, e.g. soil boring logs, SPT N-values, soil test data. By using this system, regional properties of ground can be investigated by referring data and outputting many kind of figures and tables. In the analysis using ground informations, it is indispensable to investigate the quality and quantity of informations required for analysis. This investigations can be easily carried out by using this database system.

2.3 System for liquefaction potential analysis

In this system, liquefaction potential of ground against assumed seismic motion can be calculated by various method, e.g. Seed and Idriss(1971), Iwasaki et al.(1978), Tokimatsu and Yoshimi(1983), Seed et al. (1985). Flow of the liquefaction potential analysis in this system is shown in Fig.2. Input informations are soil boring log data, soil test data and the maximum accelerations at ground surface calculated by SHAKE presented by Schnabel et al.(1972).

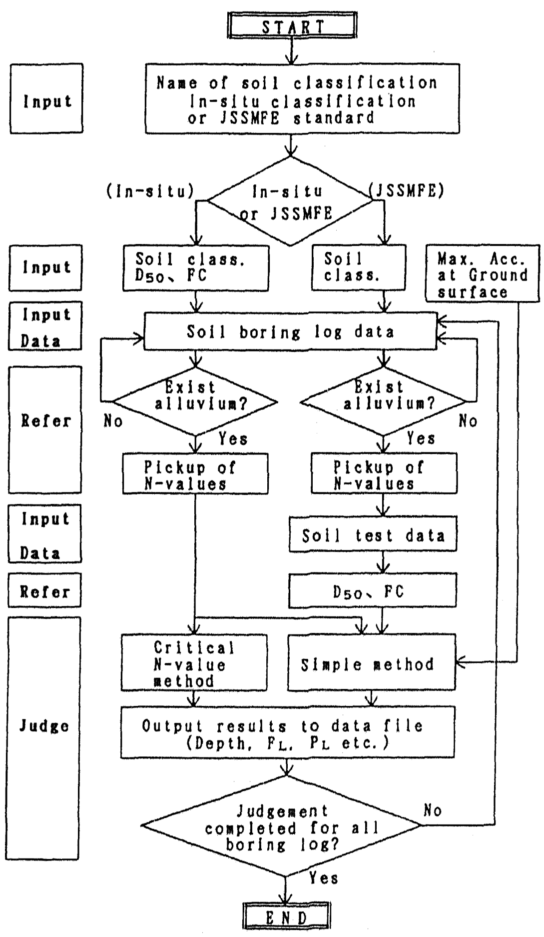

Fig.2 Flow of liquefaction potential analysis

The reference of liquefiable soil layers in the subground database is carried out by soil classification name based on JSSMFE for each layers in the case that soil tests of the layers required to the classification were sufficiently performed. If the soil test data is insufficient for the classification by JSSMFE, liquefiable layers will be referred by in-situ soil classification name described in soil boring log data.

2.4 System for estimation of seismic damages

At present, systems for analysis of damages of wooden houses, outbreak of fires and human damages have already been constructed.

Damages of wooden houses are predicted by using the empirical equations presented by Taniguchi and Iida(1986) based on the investigations of damages due to the past earthquakes. They derived two equations, Eq.1 is for the case of no liquefaction and Eq.2 is for the case that liquefaction will occur.

$$Y = 100/\{1 + m \cdot \exp(-a \cdot \alpha)\} \qquad (1)$$

$$Y = 0.667 \cdot S \cdot G \cdot I - 1.995 \cdot B \qquad (2)$$

where Y is a damage ratio of wooden houses, m and a are coefficients concerning earthquake resistance of wooden houses and uniformity of wooden houses over a region under consideration respectively, α is the maximum acceleration at ground surface by seismic response analysis based on S-wave multiple reflecting theory. And S, G, I and B are coefficients concerning the earthquake characteristics, geographical/ground structure, degree of ground liquefaction and type of housing foundation.

Outbreak of fires of wooden houses are predicted by using an empirical equation presented by Taniguchi and Iida(1985) shown as follows;

$$\log y = 0.648 \cdot \log X - 1.417 \qquad (3)$$

where y is the rate of outbreak of fires, X is the rate of completely collapsed wooden houses.

3 CASE STUDIES IN NAGOYA CITY

Case studies of estimations of liquefaction potential and of damages of wooden houses in Nagoya city by using aiding system for investigating assumed earthquakes and for estimation of seismic damages.

Nobi earthquake occurred in 1891 at northwestern area 55km far from Nagoya city, with M=8.1, and many liquefactions induced in Nagoya due to this earthquake. For verification of prediction results of liquefaction potential, Nobi earthquake were selected as the assumed earthquake. Subground informations used in this case study were the subsoil database published by Chubu-branch of JSSMFE(1990). Informations of population and number of wooden houses were in 1983.

3.1 Geological features in Nagoya

Topographies of ground surface in Nagoya are classified as alluvial plain, platform, and hilly area from western to eastern region of the city, as shown in Fig.3. Southern region of the alluvial plain is reclaimed land constructed after 17th century. Thickness of the alluvial deposit gradually increases from eastern to western region, and the maximum thickness of this deposit is more than 40m.

In the east of the alluvial plain, there is a platform, named Atsuta-platform, and in this region, diluvial deposit is outcropping. Eastern region of the city is hilly area consisted of Tertiary formation.

3.2 Estimation of the maximum acceleration at ground surface

In the estimation of the maximum acceleration at upper surface of seismic bedrock, the fault model calculating ground motion proposed by Toki and Miura(1985) was applied to the estimated earthquake fault reached below northwestern region of Nagoya city. The upper surface of seismic bedrock were set up at that of Tertiary layer.

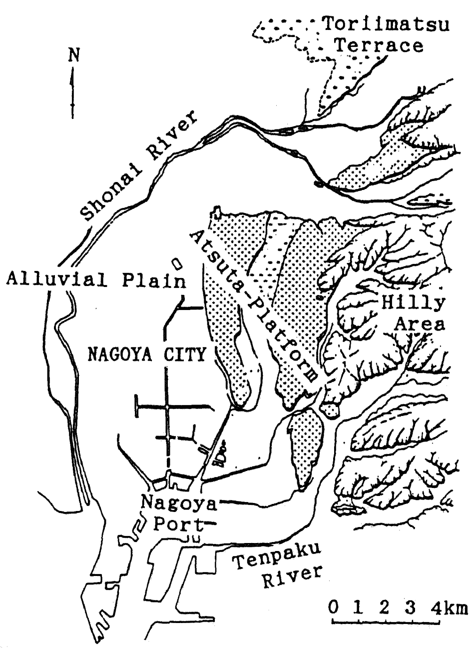

Fig.3 Topography in Nagoya city after Chubu-branch of JSSMFE(1988)

The maximum accelerations at the ground surface were calculated by using SHAKE for liquefaction potential analysis, and by S-wave multiple reflection theory for the estimation of housing damages. Figs.4 and 5 are distributions of the maximum accele-

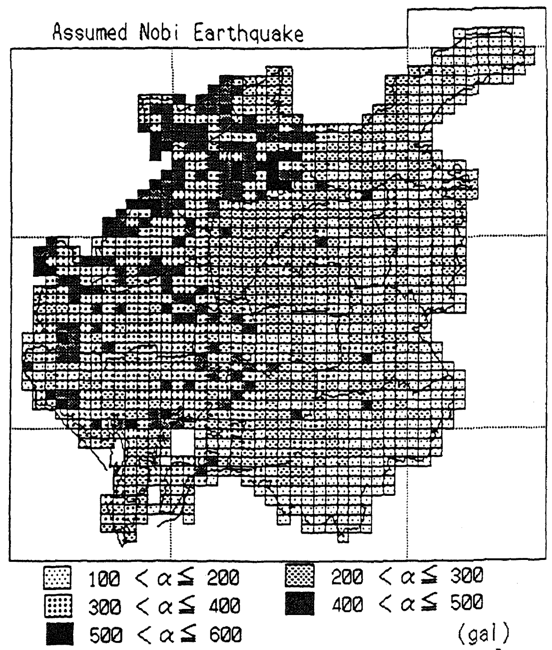

Fig.4 The maximum acceleration at ground surface based on SHAKE

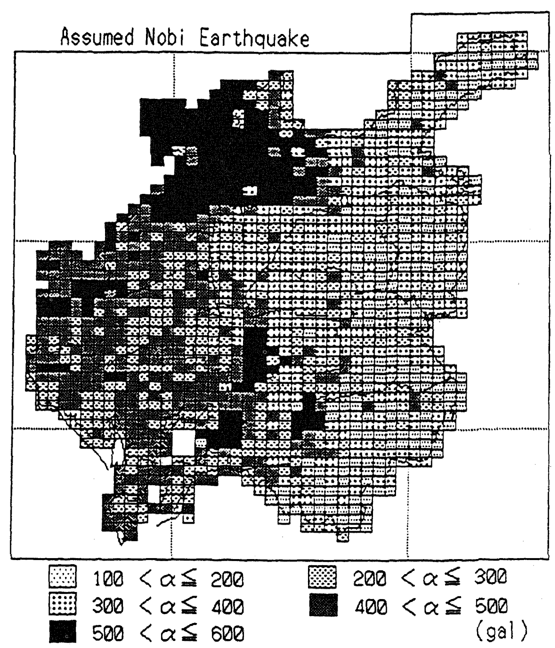

Fig.5 The maximum acceleration at ground surface based on S-wave multiple reflection theory

rations at the ground surface calculated by SHAKE and by S-wave multiple reflection theory, respectively.

3.3 Estimation of liquefaction potential

Soil properties required for estimating liquefaction potential are SPT N-values, *fine contents and/or mean grain sizes of* soil. In the subground database used in the system, mean grain size of soil is not entried. The method proposed by Seed et al. (1985) in which mean grain sizes of soil are not required, was used in this case study.

Index of liquefaction potential, P_L, was proposed by Iwasaki et al.(1978) for representing degree of liquefaction over the ground from the surface to G.L.-20m. In order to calculate P_L, factors of liquefaction, F_L, calculated by the method proposed by Iwasaki et al. should be integrated by using following equation;

$$P_L = \int_0^{20} F \cdot W(z)dz \qquad (4)$$

$$F = 1 - F_L \quad for \quad F_L < 1$$
$$0 \quad for \quad F_L > 1$$

$$W(z) = 10 - 0.5z$$

where z is the depth below ground surface. In the case of P_L<=5, possibility of liquefaction is low, and in the case of 5<P_L<=15 and P_L>15, liquefaction will be induced with high and very high possibilities.

In this study, in order to calculate P_L, factor of liquefaction calculated on the method proposed by Seed et al., $(F_L)_S$, were converted to the factor corresponding to the method by Iwasaki et al., $\overline{F_L}$, by using following equation;

$$\overline{F_L} = (M + 5.47)\alpha^{-0.500}\sqrt{(F_L)_S} \qquad (5)$$

where M is the magnitude of earthquake and α is the maximum acceleration at ground surface. And P_L were calculated by using Eq.4.

Fig.6 shows the distribution of P_L value in Nagoya indicated by 500mX500m meshes. The values of P_L are larger than 15 at northwestern region of the city, where the estimated fault by Nobi earthquake reaches below this region. Furthermore, at southern seaside area and riverside area, P_L-values are also larger than 15. Fig.7 shows the areas where liquefaction due to Nobi earthquake were actually observed. Comparing Fig.7 with Fig.6, it is seen that actually liquefied areas are well expressed by prediction results.

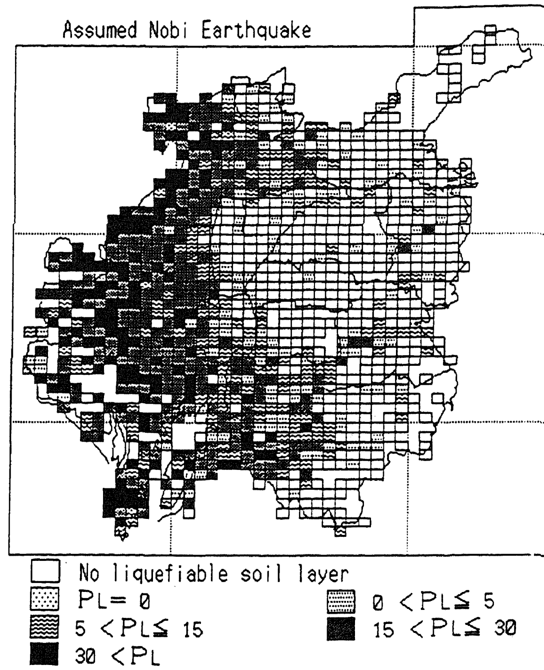

Fig.6 Estimated liquefaction potential in Nagoya city

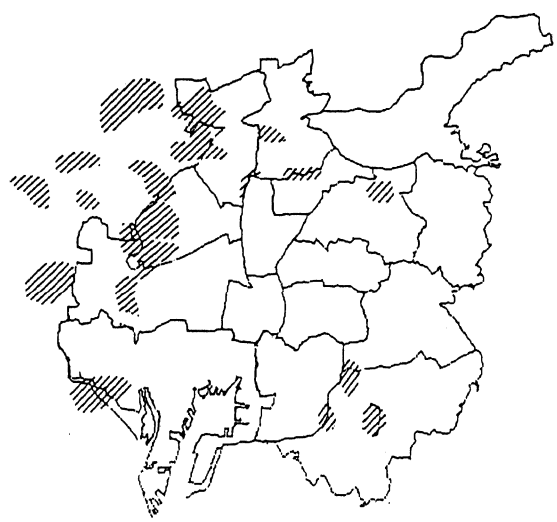

Fig.7 Actually observed areas of liquefaction due to Nobi earthquake

3.4 Estimation of damages of wooden houses

Damage ratio of wooden houses estimated by using the system is shown in Fig.8. The highest damage ratios are obtained in northwestern region of the city because of the highest maximum accelerations at ground surface induced by estimated earthquake fault below this area. At the riverside area, higher damage ratio is obtained due to

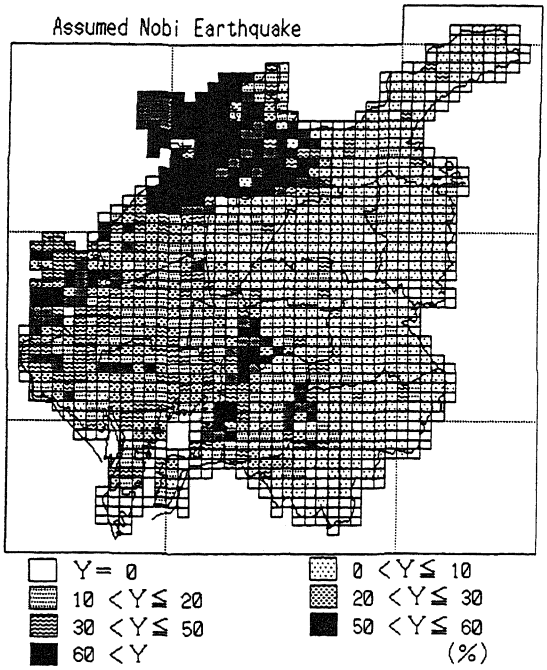

Fig.8 Estimated damage ratio of wooden houses in Nagoya city

high amplification of seismic motion within the alluvial deposit.

From the prediction results, 49093 houses will be completely collapsed, and 172435 houses will be partially collapsed due to the assumed Nobi earthquake within 533819 houses in Nagoya. And fires will be broken out at 542 houses, but the effects of spreading fire were not included in this number.

4 CONCLUSIONS

The authors described outlines and example applications of the aiding system for seismic disaster mitigation planning, consisting of aiding system for investigating assumed earthquakes, for estimation of seismic damages and for countermeasure, were shown.

In order to supply the fundamental information for seismic disaster mitigation planning, it is indispensable to construct the computer system for unified management of many kinds of informations and many-sided and rapid application of them to disaster prediction.

In such system as described here, it is very important to carry out qualitative renewal and additional collection of the informations corresponding to the changes of urban environments. It is, furthermore, indispensable to develop the most suitable and accurate prediction methods within the limits of obtained informations.

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