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PREDICTION OF EARTHQUAKE DAMAGE AND SIMPLIFIED INSTANTANEOUS EARTHQUAKE DAMAGE PREDICTION SYSTEM USING PERSONAL COMPUTER

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ABSTRACT

When considering earthquake disaster prevention measures, it is indispensable to estimate the earthquake damages in advance. Results of investigations are summarized in a report, and re-investigation are necessary for assumption of new earthquakes. To solve these problems, we have developed a new earthquake damage prediction system that includes whole method and data collected by researchers. The system is equipped with a user interface that permits calculation even by a nonexpert upon setting simple conditions, such as the scale of a fault due to an earthquake. Another system has been added to ensure easy calculation of the extent of major damage in the community within a few minutes, when an earthquake occurs, only by inputting the location of the hypocenter and the magnitude of the earthquake. These systems can operate even on a notebook type personal computer. Thus the systems excel in portability, which are operable even if power supply is suspended upon and after occurrence of an earthquake.

In addition, we propose an idea to estimate the seismic intensity and main earthquake damages in a range as wide as possible at uniform accuracy by using only the popularly existing statistical data. The earthquake damage estimation normally requires a long survey period and much money, and it is not always possible for all the self-governing bodies to carry out such an investigation. The existence of an investigation method that needs short time and low cost, even if its results are approximate, is significant. We, therefore, tried a simple damage estimation that can be positioned as the investigation prior to more detailed earthquake damage estimation investigation.

KEYWORDS

seismic microzoning; damage estimation; seismic risk reduction; instantaneous estimation; simplified estimation.

DEVELOPMENT OF EARTHQUAKE DAMAGE ESTIMATION SYSTEM

Major earthquakes in Japan have occurred frequently causing many casualties and damaging the cities. The Southern Hyogo Pref. earthquake (M=7.2) (Great Hanshin earthquake) which occurred in January 1995 killed more than 6,300 persons and brought destruction to the area around Kobe City. This high seismic activity has motivated the authorities to carry out seismic-zonation investigations to estimate as realistically as possible, detailed damage distribution from earthquakes. They have used the results to design mitigation programs and to reduce the potential damage caused by a future large-scale earthquake. These studies require a huge amount of data to estimate the distributions of seismic intensity, casualties, damage to buildings, damage to infrastructure, social and economical impacts, etc. As a consequence, it usually takes 2 to 3 years to complete a study. Further, since the investigations require considerable knowledge and a group of specialists, local governments have been entrusting the work to research organizations. The results are usually summarized in a report. It happens, however, that if an estimation is to be done for an earthquake that has not been considered in the report, an outside organization has to be called again to carry out the studies. The earthquake occurrence time and season which have great effects on the fire and casualties are often represented by worst-case scenarios. But local governments has a desire to carry out damage estimations under various conditions to prepare realistic seismic risk reduction programs.

A Seismic Damage Estimation System has been developed to satisfy the above-mentioned needs. This system allows local governments to estimate seismic damage by using effectively the methods and data that were compiled in a 2- to 3-year long period studies. The system has the following features.

- It uses the data and methods prepared during the seismic-zoning studies, to estimate seismic damage for a given hypothetical earthquake automatically.
- It allows the use of different initial conditions (season, time, and wind velocity) for the estimation of seismic damage.
- It includes a simplified method that allows a quick estimation of seismic damage. This feature could be used to make a preliminary estimation of damage distribution immediately after an actual earthquake, and take the proper emergency actions.
- Its graphic functions allow a clear and convenient presentation of the results through maps that can be easily edited depending upon the needs.
- It allows the updating of information and data. This makes it possible to consider the changes on population, services, infrastructure, etc., when doing new estimations.

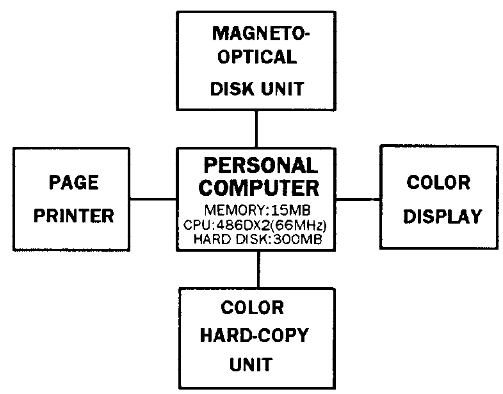

Fig. 1 The hardware needed for the system

The Hardware

Seismic-zoning investigations involve enormous amount of processing data and have generally needed the use of large computer memory size. Recent developments of the personal computers, however, make it possible now to use them in these studies. Since personal computers are easier to obtain and operate, their use can be promptly adopted by local governments. Fig. 1 shows the composition of the hardware needed for the Seismic Damage Estimating System.

The Software

The Seismic Damage Estimation System has four major functions: Precise Damage Estimation, Quick Damage Estimation, Data Management, and Demonstration. These functions are explained below.

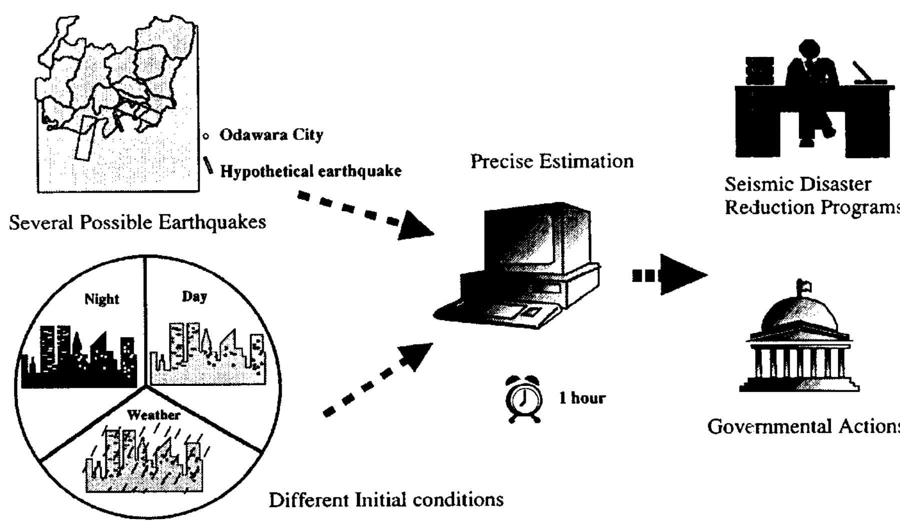

Fig. 2 Use of the precise damage estimation function for seismic risk reduction

Precise Damage Estimation. The main application of this function is for the government to estimate the damage due to various hypothetical earthquakes, and use the results to design seismic damage prevention plans (Fig.2). Further, for any given hypothetical earthquake, the initial conditions (season, time, and wind velocity) can be easily changed, thus it is possible to analyze the differences in the damage produced under various circumstances. A summary of the resulting damage estimates is shown in Table 1. The Precise Damage Estimation requires information on the fault parameters presented in Table 2. Since fault parameters are somehow difficult to be handled, the system has been designed in such a way that these parameters need to be input only once. The simple selection of the earthquake's name will start the calculation afterwards. Maps with the results are shown on the screen, while the calculations proceed in the background. Hard copies of the results can be obtained immediately, too.

Table 1 The results of the Precise Damage Estimation function

- seismic intensity distribution	- liquefaction potential	- slope failure
- mud flow	- damage to wooden buildings	- damage to other buildings
- collapse of masonry walls	- falling objects	- falling roof tiles and plaster
- damage to power system	- damage to sewer system	- damage to gas system
- damage to LPG service	- damage to telephone system	- damage to roads
- fire outbreaks and spreading	- casualties and human impact	- city service's recovery process

Table 2 Fault parameters used in the Precise Damage Estimation function

- magnitude	- location	- strike	- dip	- depth	- length
- width	- rupture velocity	- rise time	- s-wave velocity	- rupture pattern	- initial break point

Quick Damage Estimation. The Quick Damage Estimation function allows the local authorities to promptly obtain damage estimates (seismic intensity, liquefaction, slope failure, building damage, and casualties) after the occurrence of an actual earthquake, and use them to take decisions on response activities for disaster mitigation(Fig.3). Basic earthquake information (latitude and longitude of the epicenter, depth, and magnitude), is used for the quick damage estimation. As a result, the damage estimates are used simpler methods than those used for the Precise Damage Estimation function. As with the Precise Damage Estimation function, maps of results can be displayed on the screen even while calculations are still going on. Hard copies of the maps can be prepared, too.

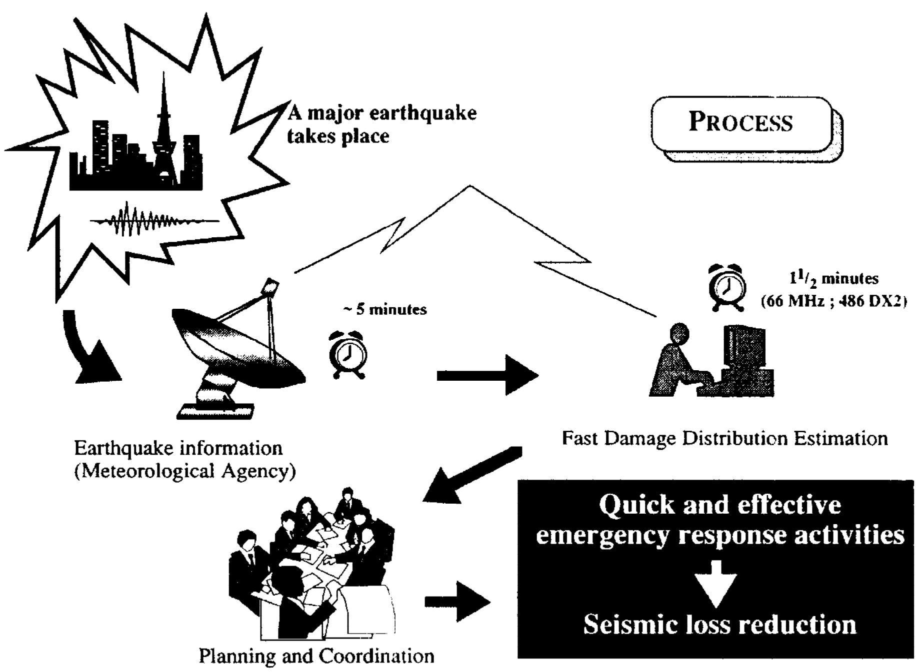

Fig. 3 Use of the quick damage estimation function for disaster mitigation

Data Management Function. This function provides easy access to the data and to the results of the damage estimation. The user can select an item from the menu and can get a display output of the desired results. The graphic functions of this system allow the editing of maps resulting from the estimation so that they can conveniently show the distribution of damage.

Demonstration Function. This function performs a slide show routine using the main results of the damage estimation. This function helps in grasping a general understanding of the system's characteristics.

SIMPLE DAMAGE ESTIMATION USING EXISTING STATISTICAL INFORMATION

The damage estimating system developed by us is now operating in several local governments. Fortunately, these local governments have not experienced such damage earthquakes as to require the immediate estimation, but the detailed estimation is utilized for preparing disaster prevention plans and preparing the scenarios for disaster prevention training. As the precondition for preparing this damage estimating system, it is necessary to implement detailed earthquake damage estimation investigation in advance, to prepare the damage estimation methods, and to collect and arrange the ground data and present situation data including building data in detail. Therefore, the period of about 3 years is required before the system is operated. But after the Southern Hyogo Pref. earthquake in January 1995, local governments consider it as an urgent necessity to prepare the earthquake disaster prevention plan. It can never be allowed nowadays to take such long period as 3 years for the earthquake damage estimation as the basis for preparing the disaster prevention plan and the preparation of the earthquake damage estimating system. As to the cost, too, it is not always possible for the local governments to allocate a sufficient budget.

We, therefore, tried to conduct the earthquake motion estimation and main earthquake damage estimations in a short time using only the relatively popular existing statistical information. Since we depend on the existing data, the result will inevitably become approximate. However, it is clear that the existence of an investigation which can be made in a short time and at a low cost is significant. For this reason, we tried the following simple damage estimation which can be positioned as the investigati on prior to the detailed earthquake damage estimation investigation.

Estimation of Earthquake Motion

When the earthquake motion distribution is estimated in the earthquake damage estimation investigation, normally the ground condition is investigated as in detail as possible and made into a model. This requires the work to collect and arrange a huge amount of data including boring data. Here, however, we introduce an example where the computation was made by a rather simple method to estimate the seismic intensity distribution in a wide area using existing data instead of collecting such a huge amount of data. The subject was the Hanshin Region where the Southern Hyogo Pref. earthquake occurred.

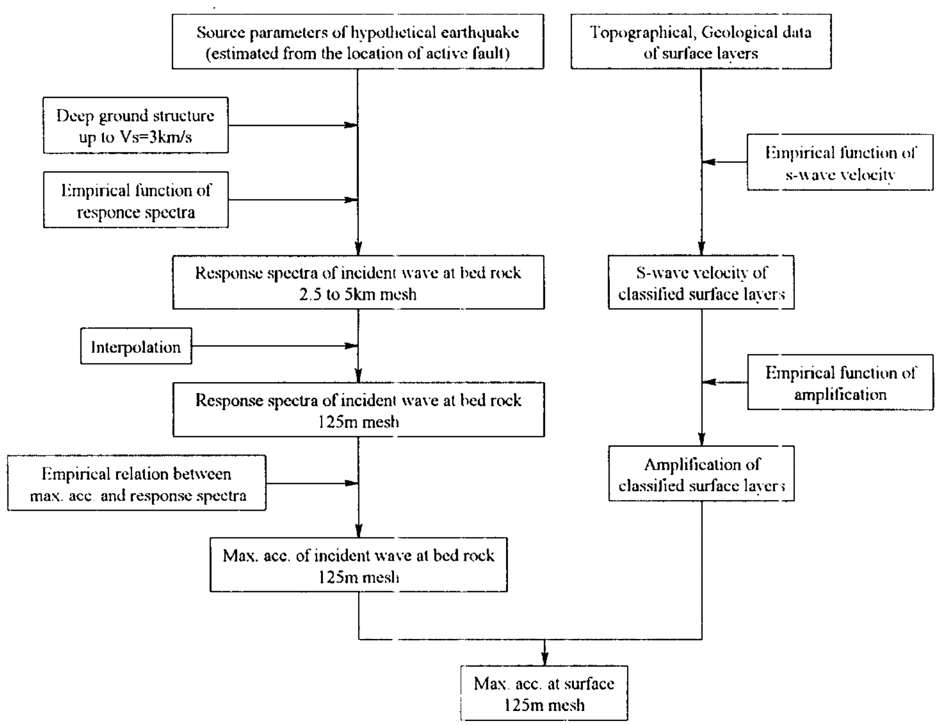

Fig. 4 Flowchart of the simplified method for earthquake ground motion estimation

Outline of Method. Fig. 4 shows the flow of the rather simple estimating method for earthquake motion distribution used in this case. In this method, it is possible to estimate the earthquake motion distribution if the location and size of the fault, the topography of the objective area, and the classification of surface geology are given. In this example, the fault model is set from the aftershock distribution within 24 hours after the main shock, because the estimation is made on the actual occurrence of the Southern Hyogo Pref. earthquake.

The response spectrum at seismic bedrock(Vs=3km/s) was calculated at the intervals of about 2.5 to 5km, by a semi-empirical method considering the fault model. This was converted into the acceleration referring to the empirical formula of Midorikawa and Kobayashi(1979) and then interpolated in the value of about 125m mesh. Fig. 5 shows the incident acceleration in the seismic bedrock. It well expresses the spread condition of the seismic intensity due to the effect of the fault model, spread linearly, which cannot be expressed by the point source. It also reflects the fault rupture which propagated from epicenter to the northeast and southwest, then the calculated values become large at the northeast end of the fault.

As the data to evaluate the amplifying characteristic of the seismic motion by the surface layer, the topographical distribution and surface geological distribution were used as the information obtainable uniformly over the area. In this example, since the region, surrounded by the mountainous area and the coast, is radical in change of ground condition. So, the mesh used was very small (about 125 x 125m), as shown in Fig. 6. As to the amplification factor due to the surface layer, the average s-wave velocity was given for each type of ground, referring to Table 3 by Matsuoka et al. (1993). Next, the amplification factor for each type of ground was set by the relational expression (1) between the s-wave velocity and acceleration amplification factor by Midorikawa et al. (1980).

$$\begin{aligned} A &= 5.5 \qquad\qquad\quad (AVS \leq 200m/s) \\ A &= 40 \times AVS^{-0.374} \quad (AVS \geq 200m/s) \end{aligned} \tag{1}$$

A : amplification factor of acceleration
AVS : average s-wave velocity of surface layer (0 to 30m)

As to the reclaimed land of the coast, another value was set from the existing s-wave velocity data because it consists mainly of weathered granite, materials a little stiffer than the reclaimed land as usual in Japan especially near the Tokyo Region. It should be noticed that properties should be replaced local characteristics.

Table 3 Average s-wave velocity of geomorphological unit (after Matsuoka et al.(1993))

Surface geology	Geomorphological unit	Average Vs(m/s)
Alluvial layer	Delta, Back Marsh	205
	Sand Bar, Dune, Natural Levee	238
	Fan	274
	Others	222
Diluvial layer	Loam Plateau	328
	Low-relief hill	347
	Gravel Plateau	414
	Others	349
Reclaimed Land		205
Artificial Transformed Land		330

Calculation Results. By multiplying the acceleration at the seismic bedrock by the amplification factor of the surface layer, the acceleration distribution at the ground surface was calculated and the result is shown in Fig. 7. In the narrow band-like area of the Hanshin Region between the Osaka Bay and the Rokko Mountain area, which was so-called the "earthquake disaster belt", most severely damaged by the Southern Hyogo Pref.

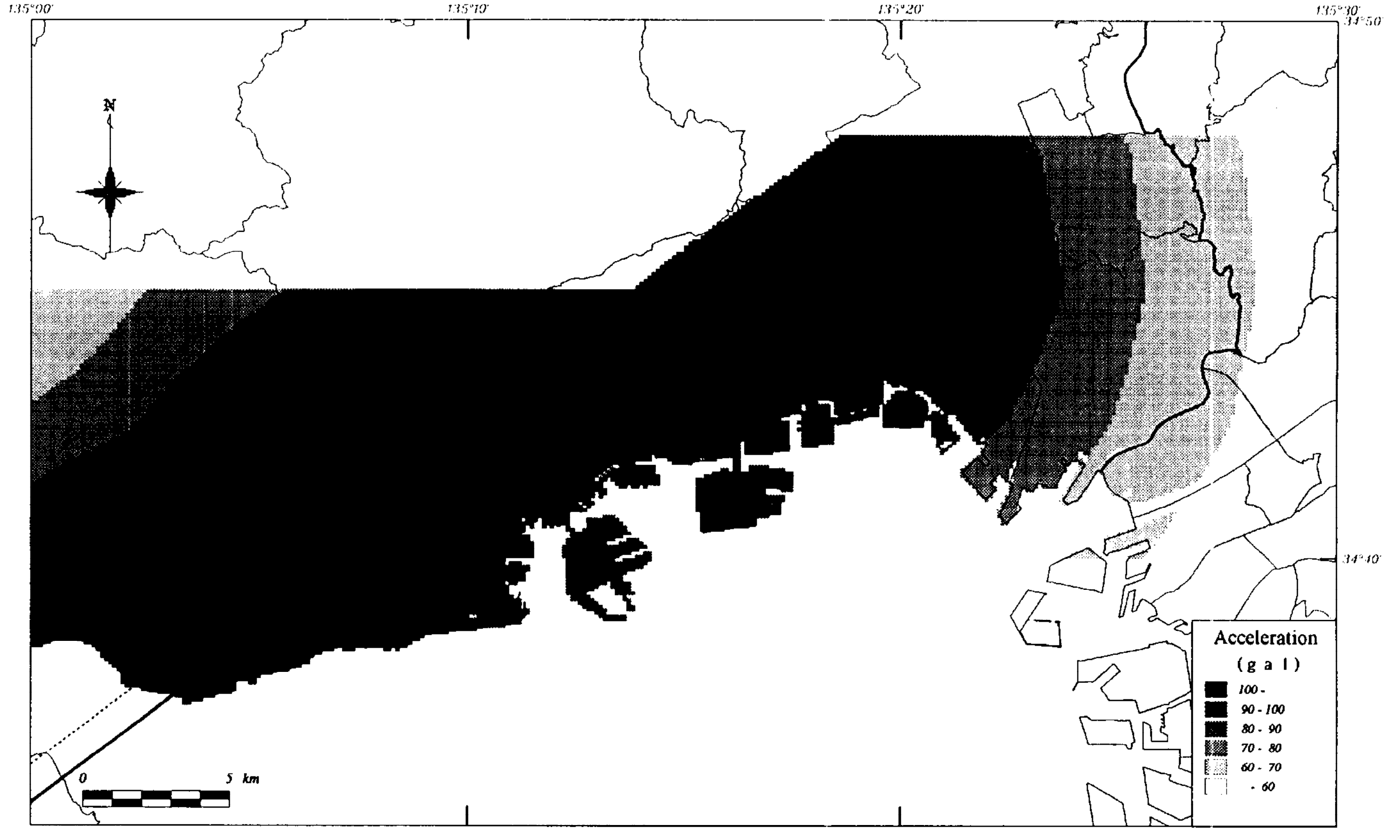

Fig. 5 Estimated incident acceleration distributions at bed rock

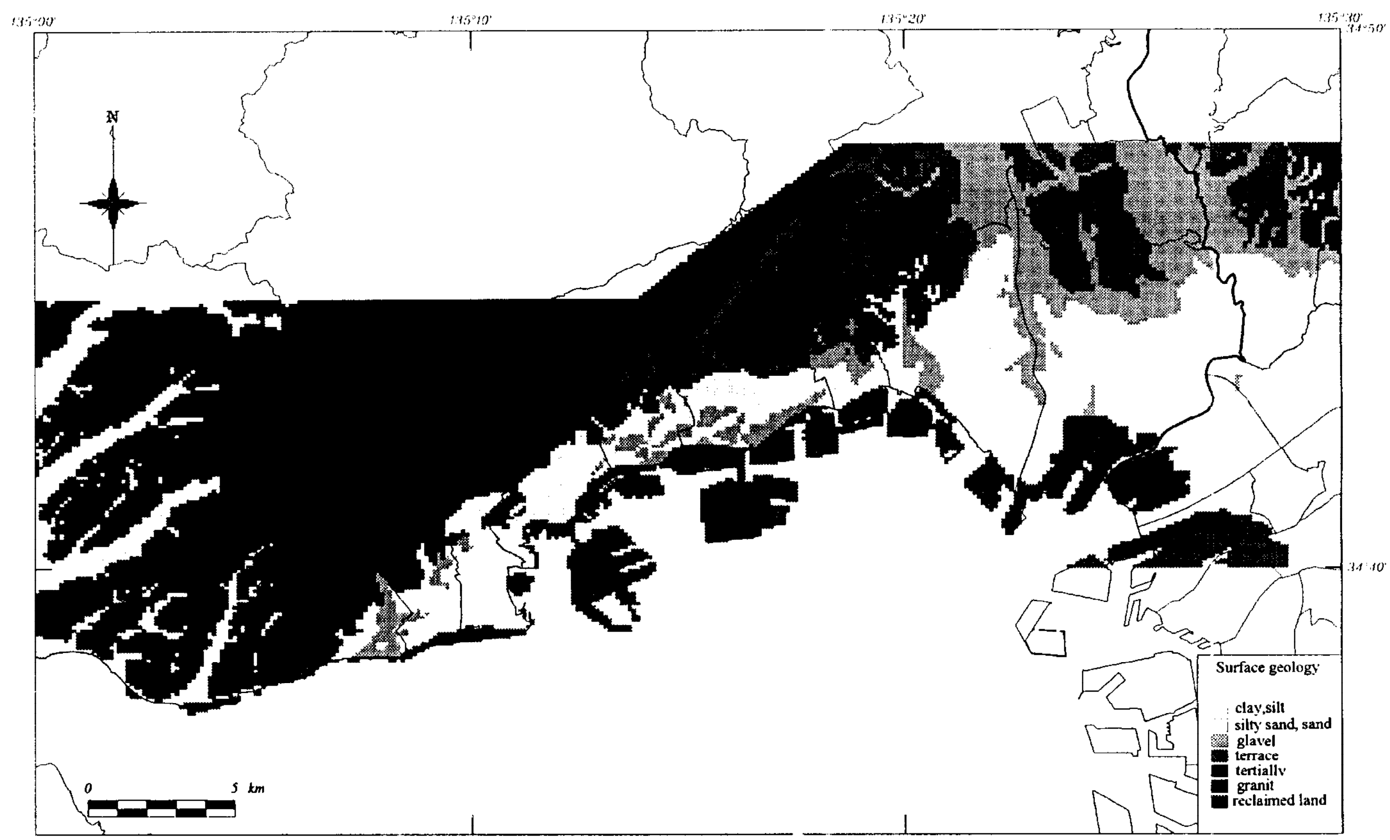

Fig. 6 Subsurface geological distribution (Hanshin district)

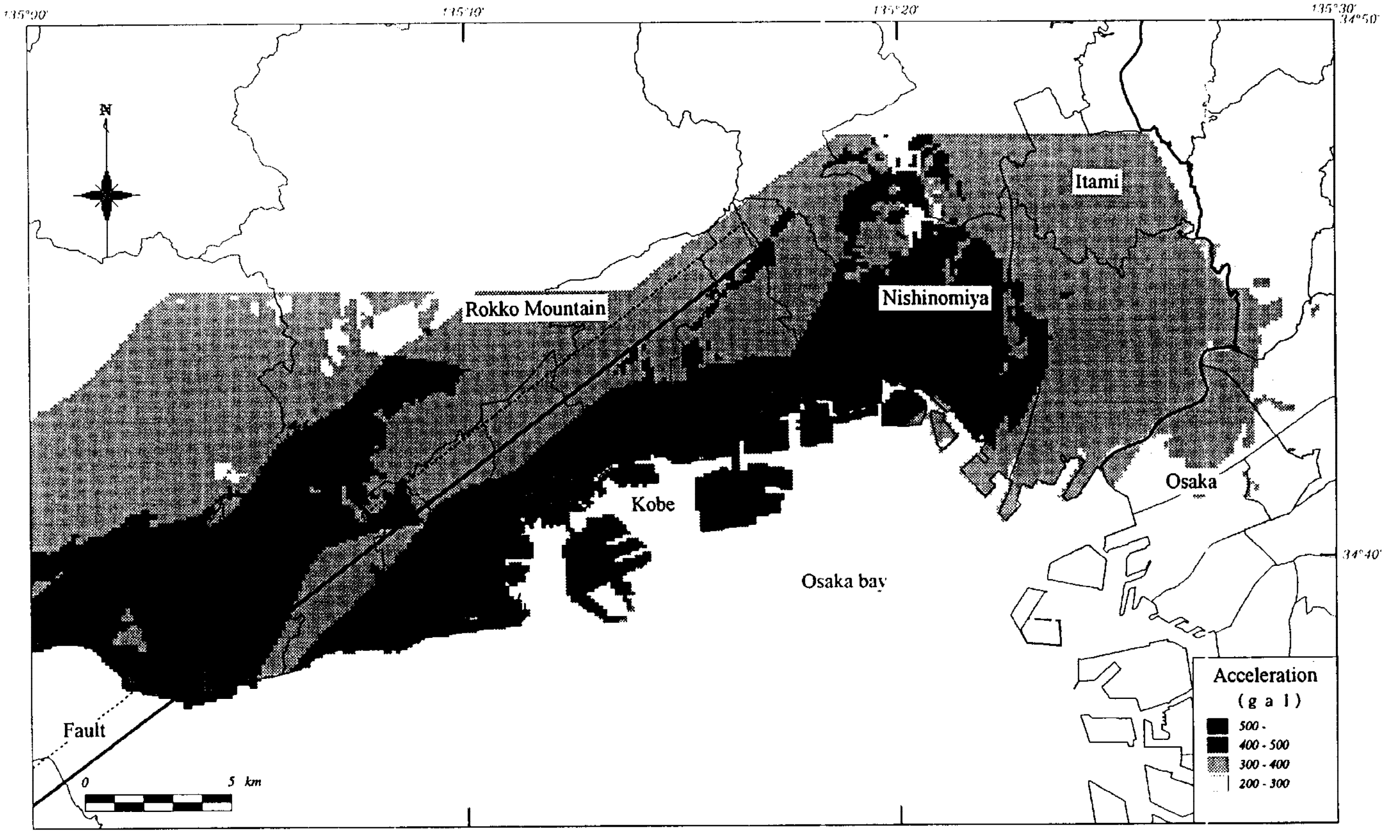

Fig. 7 Estimated acceleration distributions at surface

earthquake, the estimated acceleration was the largest. In the reclaimed land, the acceleration is smaller in comparison with the land portion and the acceleration is large enough even in the Itami and Nishinomiya areas, east of the fault. These reflect the fault rupture propagation and the difference of ground condition. The distribution of acceleration could reproduce the tendency enough to describe the damage situation in the Hanshin Region.

Estimation of Building Damage

When the building damage is estimated in the earthquake damage estimation investigation, normally the taxation ledger is collected from each city, and the current situation data base is prepared by corresponding the address and mesh to each building. By using such data as structure, number of floors, building year, and floor area, included in the data base, the strength of the building can be calculated. By comparing the strength and the seismic force, the damage is estimated. Such data base is indispensable for the damage estimation of the buildings, but a lot of labors required for preparing a data base. We, therefore, tried to make the damage estimation by preparing a data base in a short time, by utilizing the existing statistical data. Fig. 8 shows the flow.

As the building-related statistical data covering a wide area with uniform standards, the housing statistics are available. This includes the aforementioned information necessary for the damage estimation, and the totalizing unit is for each city. In order to convert these data into the data for each mesh, we used the census data. The census data include the population distribution data for each mesh of 1km, and the conversion was made assuming that the population and the number of houses are in a proportional relationship. Since the housing statistics do not include stores and offices, we covered them using the office statistics. In this case, however, the difference in component ratio due to the city scale, calculated from the existing tendency, was taken into consideration. As a result of the above flow, we could prepare a data base which can be used for the damage estimation in units of 1km mesh. This flow is an idea applicable to all the areas in Japan, indicating the possibility of simple damage estimation with uniform standards. Fig. 9 shows an example of the

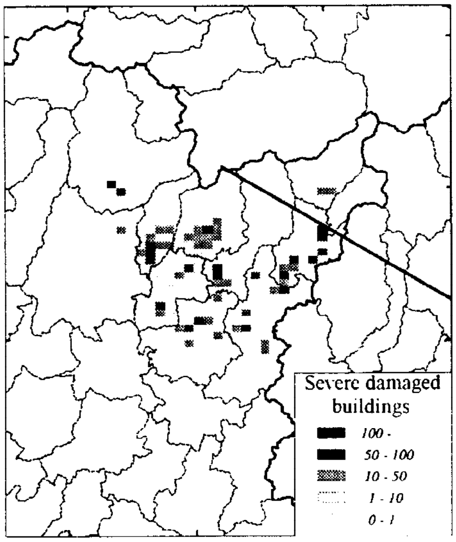

Fig. 9 Example of estimated buildings damage distributions

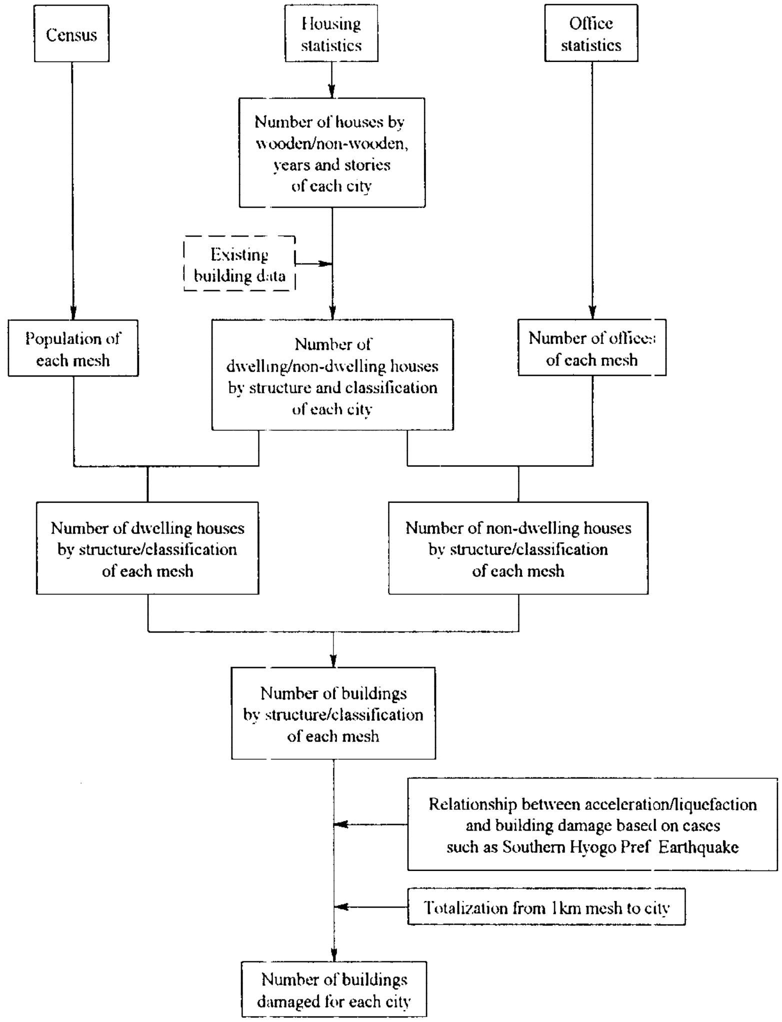

Fig. 8 Flowchart of the simplified method for buildings damage

CONCLUSION

We developed a system that can be operated even on a notebook type personal computer, which can make the earthquake damage estimation so far summarized in the form of a report, thus making it possible for the personnel in charge of a local government to conduct the simulation assuming various cases. We also showed an idea to conduct simple damage estimation on main items in a short time using only the existing data. We consider such idea of simple damage estimation can be referred to for the damage estimation in developing countries where it is relatively difficult to obtain data. It is, of course, preferable that the earthquake damage estimation be in detail, but the level of the damage estimation required by the administrative organ is not uniform due to the difference in social and economic environment. The idea of earthquake damage estimation to meet the level required is called for. Together with the enhanced accuracy of the damage estimation, it will be necessary to establish an idea of damage estimation to meet the required level.

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