REAL-TIME ASSESSMENT OF EARTHQUAKE DISASTER IN YOKOHAMA BASED ON DENSE STRONG-MOTION NETWORK

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SUMMARY

This paper describes a system for REal-time Assessment of earthquake Disaster in Yokohama (READY System). The system consists of three sub-systems; 1) the dense strong-motion monitoring system, 2) real-time seismic hazard and risk assessment system, and 3) damage information gathering system. Using the ground motion data from the strong-motion monitoring system, the real-time assessment system computes ground shaking hazard, liquefaction hazard, and wooden-house damage within 20 minutes after the event. In the mapping, a fine mesh system with a size of 50m x 50m is adopted because of strong variation of local soil conditions in the city. The damage information gathering system is constructed in order to overlay the actual damage information which is gradually obtained after the event on the estimated damage map.

INTRODUCTION

The 1995 Kobe, Japan earthquake gave a great impact on disaster management strategy. Just after the earthquake, few immediate emergency response was taken by the national and local governments, which might allow the spread of the disaster. This is due to lack of prompt information on the disaster. As a result, the national and local governments in Japan began to develop the earthquake disaster information systems [Yamazaki et al., 1998]. One of the most sophisticated ones is the system for REal-time Assessment of earthquake Disaster in Yokohama (READY System). Figure 1 shows the outline of the system which consists of three sub-systems; 1) the dense strong-motion monitoring system, 2) real-time seismic hazard and risk assessment system, and 3) damage information gathering system. This paper describes the READY system.

DENSE STRONG MOTION MONITORING SYSTEM

The city of Yokohama is the second largest city in Japan whose population is 3.3 millions. Within 433 km^2 of the city, accelerographs at 150 free field stations are installed for ground shaking monitoring [Ishihara et al., 1996]. Spacing between stations is about 2 km. Locations of the stations are shown in Fig. 2. In addition to the accelerographs at ground surface, borehole accelerometers are installed at 9 stations for liquefaction hazard assessment. A high precision digital accelerograph is used to record weak to very strong ground motion. Ground acceleration up to 2000 cm/s^2 is registered on an IC memory card with 18 bits A/D resolution. The absolute time of the data is ensured by a GPS receiver.

These stations are connected to three observation centers, the disaster preparedness office of the city hall, the fire department office of the city and Yokohama City University, by the high-speed and higher-priority telephone line. Each observation center gathers the data from the stations independently for data exchange and supplement among the centers. At 24 stations, backup communication systems by satellite, opitical fiber line or radio are available. The full operation of the monitoring system started on May, 1997.

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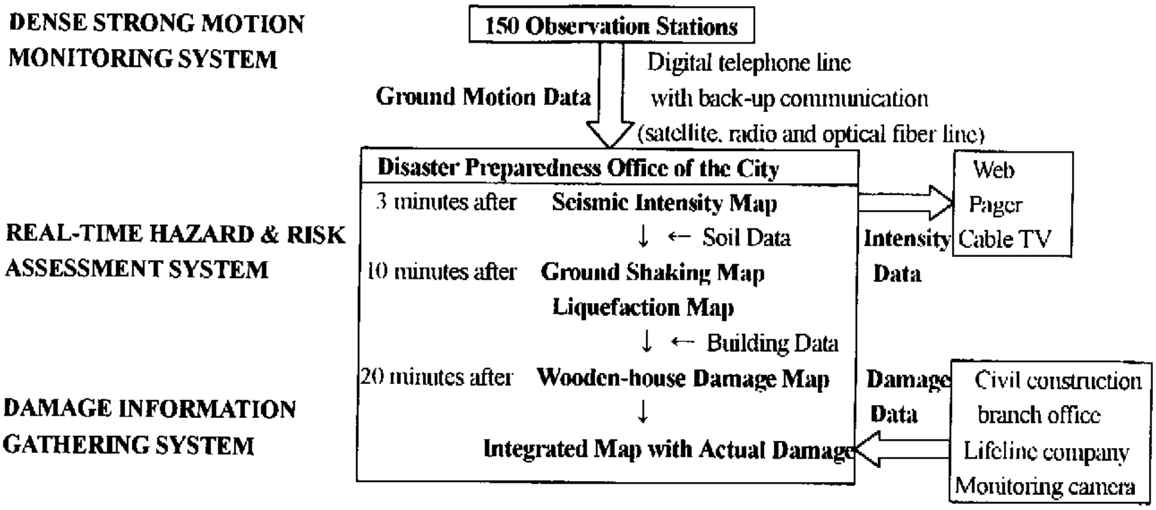

Fig. 1 Outline of the READY System

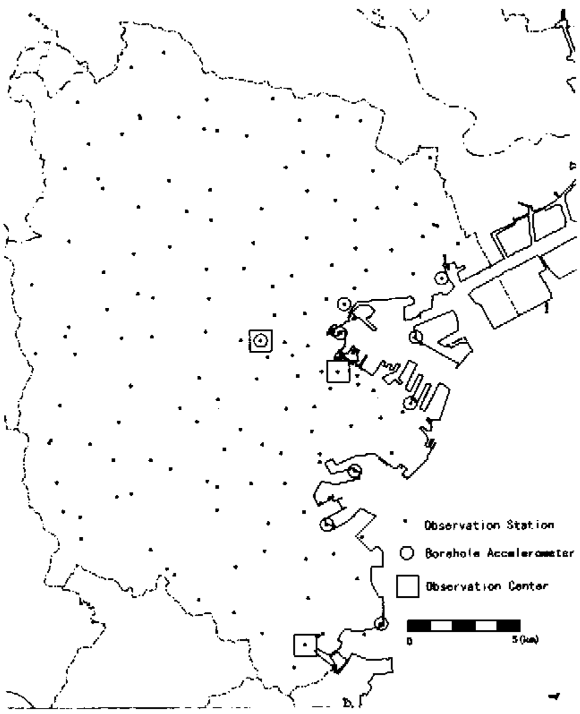

Fig. 2 Locations of Observation Stations and Centers

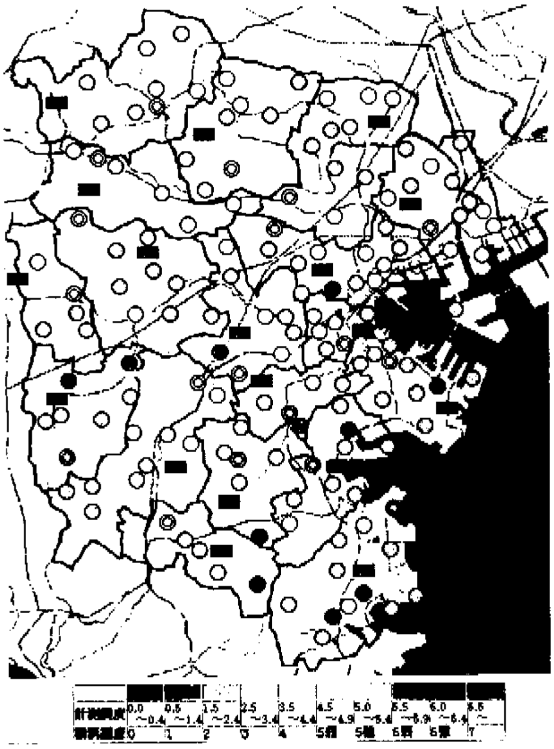

Fig. 3 Seismic Intensity Map

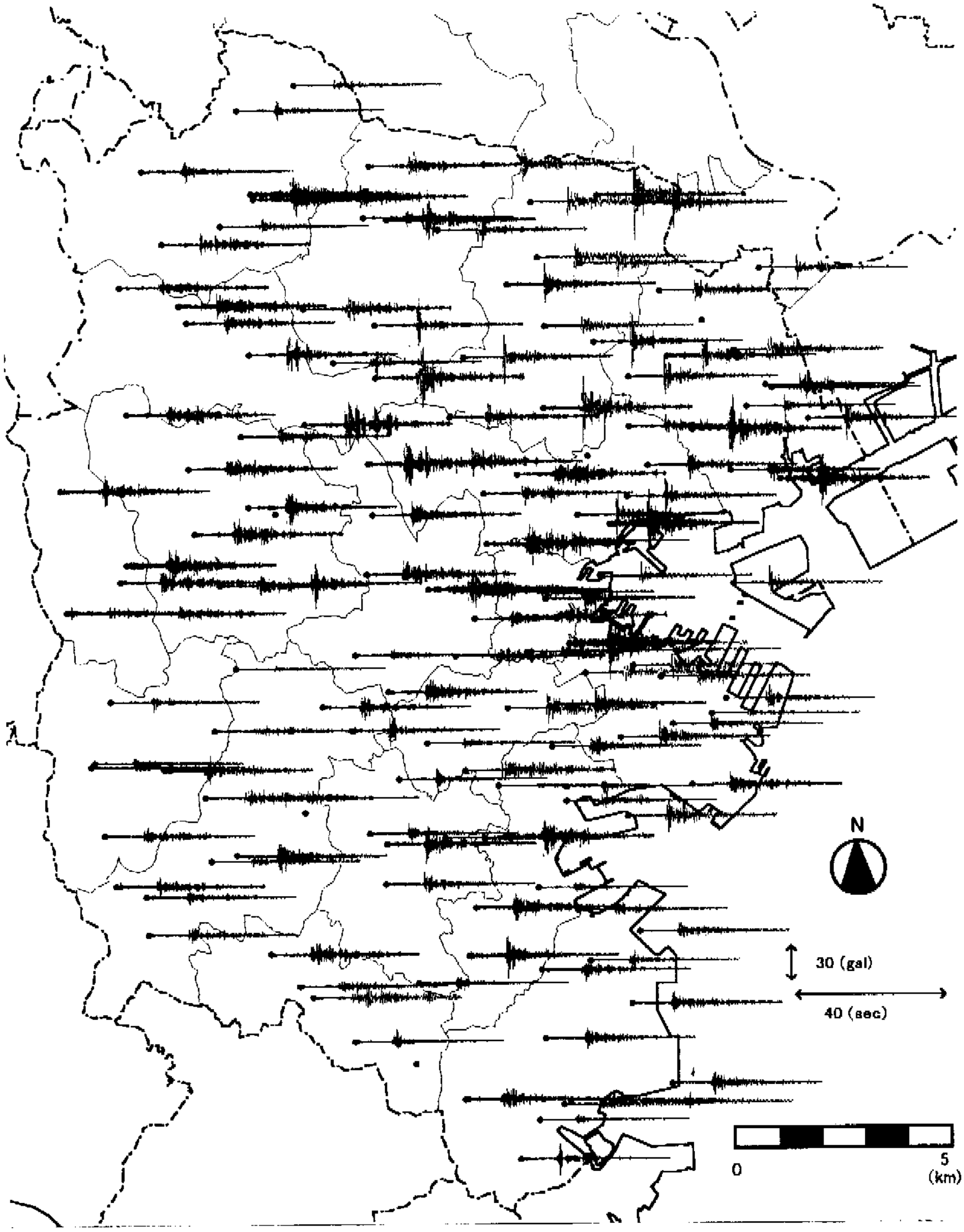

Fig. 4 Acceleration Time Histories at Dense Strong-Motion Stations in Yokohama

When the accelerograph is triggered by an earthquake, the station computes ground-motion parameters such as the measured seismic intensity, peak amplitudes, response spectral amplitudes and duration. These parameters are automatically reported to the centers. The reported seismic intensity data is conveyed to the city officials by the pager, and the intensity map of the city is drawn within a few minutes after the earthquake. The map is immediately open to the public through the internet (www.city.yokohama.jp/me/bousai) and local cable TV. An example of the map is shown in Fig. 3. The map is utilized as the most early information for disaster management.

Figure 4 shows acceleration time histories of north-south component during the earthquake (M5.0) on July 9, 1997. In the earthquake the records were obtained at 145 stations of the 150. Large variations are found in amplitudes, frequency contents and duration of the records. The observed peak accelerations in the city vary from 3 to 44 cm/s^2. These variations suggest large effects of local site conditions in the city. The data have been analyzed to evaluate local site effects in the city [Toshinawa et al., 1998].

REAL-TIME SEISMIC HAZARD AND RISK ASSESSMENT SYSTEM

In order to grasp a scale of the disaster and its spatial distribution immediately after the event, the ground motion data from the stations are used for the seismic hazard and risk assessment. The assessed items are ground motion, liquefaction and building damage. The various GIS (Geographic Information System) data which have been built by the different departments of the city, are gathered and compiled for the assessment. The operation of the assessment system started on June, 1998.

In the mapping of ground motion hazard, the city is divided into 170,000 elements with the mesh size of 50 x 50 meters. The fine mesh system is adopted because of strong spatial variation of the geological and geomorphological conditions in the city. The soil condition of the city is classified into 268 types based on geological and geotechnical data. The data from borings or measurements of S-wave velocity are used to build up the generalized underground model for each soil type. The amplification factor of each soil type is prepared for different ground motion levels based on the computation by the equivalent linear method. Figure 5 shows the simplified soil classification map of the city. The amplification factor of the corresponding soil type is assigned to each element.

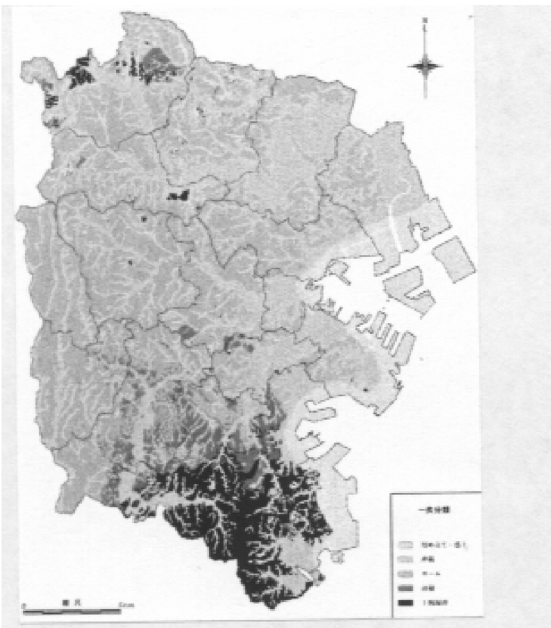

Fig. 5 Simplified Soil Classification Map

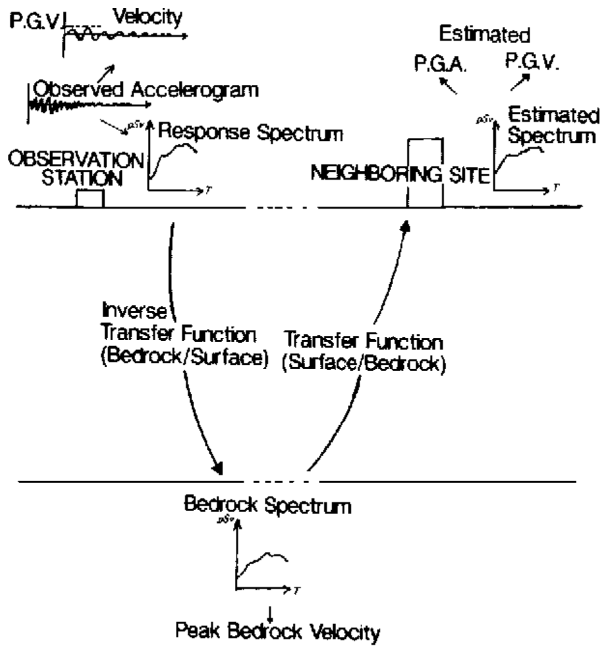

Fig. 6 Flow of Ground Motion Mapping

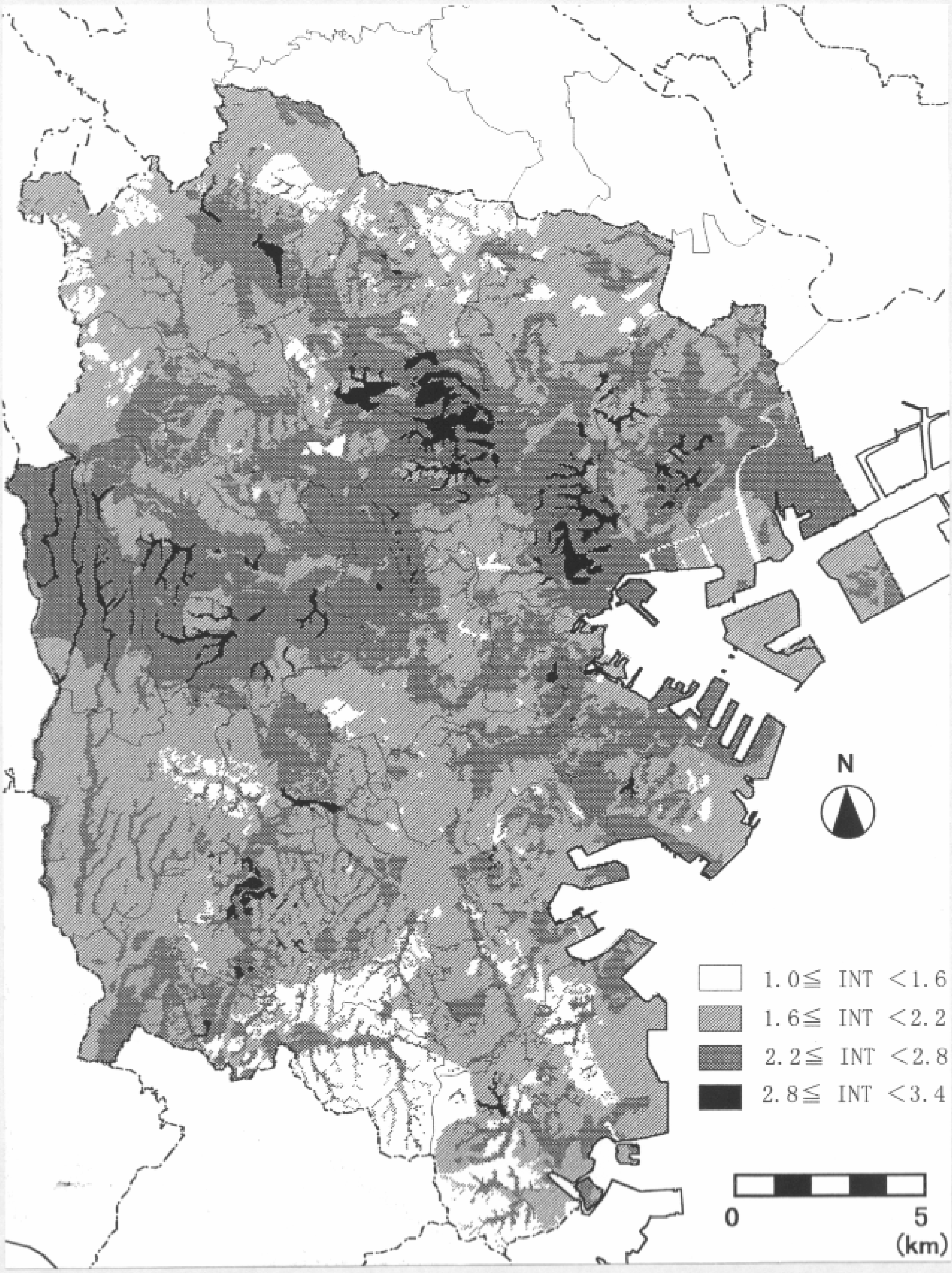

Fig. 7 Detailed Ground Shaking Map

To eliminate the site effects from the observed ground motion, the bedrock motion spectrum at each station is estimated by dividing the observed response spectrum by the computed amplification factor. To evaluate the amplification factor accurately, the S-wave velocity of ground down to the bedrock (Tertiary rock) is measured at all the 150 stations. The ground motion spectrum at each element of the fine mesh system is computed by multiplying the bedrock motion spectrum at the neighboring station by the amplification factor at the element. The flow of the ground motion assessment is shown in Fig. 6. Thus, the very detailed ground shaking map is constructed by using the observed ground motion records and the underground model, as shown in Fig. 7.

Liquefaction hazard is also assessed. In this assessment, a dynamic load induced in a soil element during an earthquake is evaluated not by the record at surface, but by the record of the borehole accelerometer at bedrock. The liquefaction resistance of soil is calculated by the method adopted in the specifications for highway bridges [Japan Road Association, 1996]. The liquefaction potential for each element of the fine mesh system is determined by comparison of the liquefaction resistance with the dynamic load.

Although there are many commercial buildings in the city, the majority of the buildings in the city are wooden houses. Generally, they are more vulnerable to strong shaking than non-wooden buildings such as reinforced concrete buildings. Accordingly, the assessment of the seismic risk of wooden houses is included in the system. The GIS database of about 450,000 wooden houses is built up by the data matching of the fixed asset tax inventory and the digital map. The dynamic vibration characteristics of each house are assigned according to the construction age and the types of structure, use and roof. The drift of the house is computed by using the response spectrum of ground motion, to determine the degree of the damage. The distribution of the wooden-house damage is mapped and displayed with arbitrary scale. Figure 8 shows the close-up of the damage map with other information such as locations of hospitals, refuges and major roads for emergency transportation.

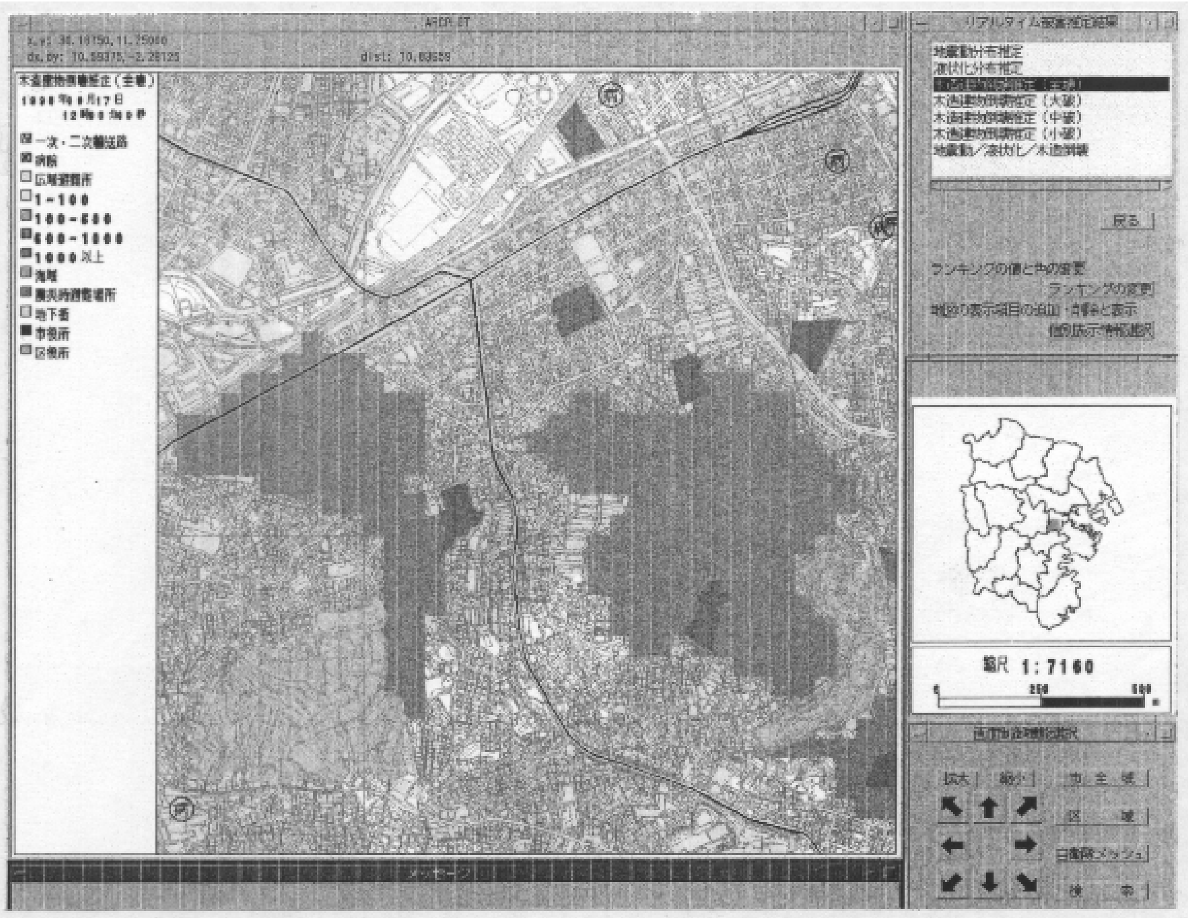

Fig. 8 The Wooden-House Damage Map with Locations of Hospitals, Refuges and Major Roads for Emergency Transportation

The ground motion data such as seismic intensity and response spectrum are reported from the stations within a few minutes after the event. Then, the ground motion and liquefaction hazards are computed in several minutes, and the wooden-house damage is assessed in ten minutes. Thus, the hazard and risk maps are created within twenty minutes after the earthquake, almost in real-time, so that the maps can be used for selecting strategy of emergency response activities.

DAMAGE INFORMATION GATHERING SYSTEM

The damage information gathering system is constructed to overlay the actual damage information that is gradually obtained after the event on the estimated damage map. The operation of the gathering system started on April, 1999. The city has an agreement with about 500 civil construction firms. When the seismic intensity larger than 5 in the Japanese scale (approximately 7 in the M.M. scale) is observed, they will immediately survey the damage to road structures on the major 93 roads, and report the damage to the 18 civil construction branch offices of the city.

The damage information reported to the 18 branch offices is transmitted to the city hall in the form of the GIS data by the intranet GIS system. The schematic figure of the intranet GIS system is shown in Fig. 9. The damage GIS data are gathered in the GIS system at the city office, which links with the real-time assessment system. The damage GIS data such as the damage of the road and restriction of the traffic are overlaid on the estimated damage map in order to up-to-date the damage information.

The information on the lifeline damage and restoration is also reported to the city hall from the telephone, gas and electricity companies and the water department of the city. The data are displayed on the monitors at the city hall and the 18 ward offices of the city. The data are independent of the damage information gathering system so far, but it is planed that they will be taken in the gathering system. The monitoring cameras have been installed at the top of the skyscraper and on the helicopter. The images by the cameras are sent to the city hall by the radio transmission, and are used as the actual damage information.

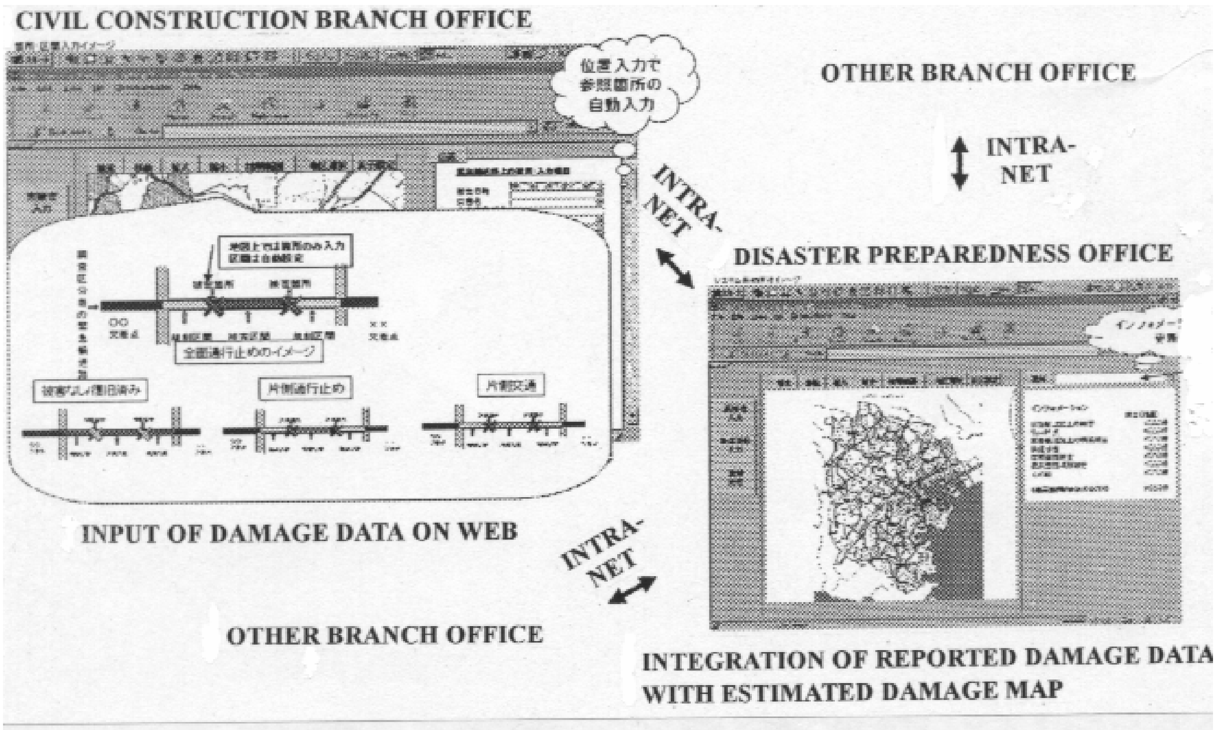

Fig. 9 Schematic Figure of Intranet GIS System

CONCLUDING REMARKS

The configuration of the READY system has been described in this paper. The main objective of the system is better decision of emergency response and recovery, but it also gives benefits to earthquake preparedness activities. For example, precise seismic hazard maps are going to be prepared from the analyses of the observed ground motion data from the 150 stations. The maps are useful for disaster planning of the city and for earthquake education of citizens by awareness of regional seismic risk. Thus, the system can be utilized not only at emergency, but also at all the stages of earthquake disaster management such as preparedness, emergency response and recovery.

Although the system is one of the most sophisticated systems among the existing early earthquake damage assessment systems, the system has several points to be improved. At present, the damage information can be used for the administration of the city. However, the information should be open to the citizens so that they can select appropriate actions to minimize the disaster following after the event. For this purpose, the information is necessary to be interpreted in a simple form so that the citizens can easily understand meanings of the information. Exchange of the information with the other disaster information systems is also one of the issues to be considered. Further improvement of the READY system is being discussed to solve the problems remaining.

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