POST-EVENT DATA COLLECTION USING MOBILE GIS/GPS AND DEVELOPMENT OF SEISMIC EVALUATION TECHNIQUE FOR DAMAGE

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SUMMARY

This paper presents mobile system for post-event data collection (1) to realize effective methodology to collect urban disaster information during post-earthquake reconnaissance, with combined using of GIS (Geographic Information System) and GPS (Global Positioning System) into mobile computer, (2) to propose useful disaster management tools for emergency response using GIS/GPS, (3) to apply to rapid assessment and detailed survey of damaged buildings, lifelines and other systems in urban area for risk to second-disaster due to their collapse. Also, principal cause of building damage was investigated. Using GIS, building damage state was analysed in correlation to geology, ground failure, building structure and age, and simulated ground shaking. The damage of buildings was strongly related to kinds of structure and age. However, town blocks occupied with many older buildings were not certainly suffered severe damage. Simulated intensity distribution of maximum acceleration of ground shaking based on FDEL (Frequency-Dependent Equivalent Strain for Equi-Linearized Technique) is well correspond to the building damage distribution. It can be roughly concluded that damage of buildings due to the 1995 Hyogo-ken Nanbu earthquake was caused mainly by strong ground shaking due to the earthquake.

INTRODUCTION

The disasters caused by the 1994 Northridge earthquake in the USA and the 1995 Hyogo-ken Nanbu (Kobe) earthquake in Japan are so extensive that diverse research areas must be activated in order to learn from the calamity. A GIS is expected to constitute a useful database tool for basic studies of disaster analysis and mitigation. This is also useful as judgmental information in “disaster information management assistance” activities in the post-earthquake period, which are being implemented in part of emergency operations by local governments (Kameda, et al. 1995). This research is executed toward making performance criteria for urban infrastructure design and for urban disaster management systems. The research is ongoing,

(1) to establish methodology for rapid assessment on distribution of building and/or lifeline damage using GIS and GPS;

(2) to grasp necessary and useful pre-event information (classified data), for example, basic maps of cities, building status, each lifeline network, surface ground condition, soil and rock foundation, etc., and to make database for urban disaster management;

(3) to develop mobile data acquisition system using GIS and GPS, to collect damage data in post-event reconnaissance;

(4) to solve problems in hardware and software systems for data collection in field survey;

(5) to solve problems for input to the system and telecommunication to other machines;

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(6) to make criteria for building damage assessment and for the unified usage necessary for efficient use of building damage information in the crisis management; and

(7) to increase accuracy in disaster analysis for damage prediction and mitigation.

Next, based on data from Nishinomiya City, interrelations among various aspects of the Great Hanshin-Awaji Earthquake Disaster are presented. GIS-based information allows us to understand the state of the disaster caused by the earthquake, as follows;

(8) correlation among geology, ground shaking, ground failure, damage of buildings and lifelines, their restoration process, number of persons at emergency shelters and others;

(9) difference between damage distributions of lifelines and buildings;

(10) relations between lifeline recovery and number of refugees in emergency shelters; and

(11) difference between technical and administrative issues on damage assessment of buildings.

MOBILE DATA ACQUISITION SYSTEM USING GIS AND GPS

A mobile data acquisition system using GIS (Photo 1 and Fig. 1) is developed for inspectors and/or researchers who want to collect and/or update building and lifeline facility data for the present status in pre-event period and their damages in post-earthquake reconnaissance. In this system, GPS receiver provides positions and field information for GIS functions (Photo 2 and Fig. 2). So the system enables operators to easily navigate to features and to update GIS data when performing routine maintenance or inspections for buildings and other urban facilities. Data collection system's hardware and software are as follows.

(a) Field computer Requirements

Hardware: Field computer: IBM-compatible pen PC with Type II PCMCIA slot; Mitsubishi Mobile Computer 'AMiTY SP'.
Operating system: Microsoft Windows 95 for Pen Computing.
Screen: 7.5 inch LCD; DSTN/VGA Color (640×480 dots).
CPU: 80486 DX4/100MHz.
RAM: 32MB.
Hard disk: 340MB.
Input devices: Pen or Keyboard.
Size: A5 file size (240×170×30mm).
Weight: 1.1kg (including 1 battery).

- GPS Receiver Specifications
  Receiver General: 3-channel digital GPS receiver; Trimble Mobile GPS Card Receiver 'Direct GPS'.
  Update rate: 1 second (typical).
  Acquisition time: < 2 minutes (typical).
  Accuracy (typical): Autonomous: 100 meters
  Differential GPS: 2-5 meters
  All GPS receivers are subjected to degradation of position and velocity accuracy under U.S. Department of Defense-imposed Selective Availability (S/A). Positions may be degraded up to 100 meters 2D RMS.
  PCMCIA card weight: 0.03kg.
- GPS Antenna
  General: Low-profile micro strip patch with magnetic mount.
  Size: 6.7 cm diameter×1.9 cm height.
  Weight: 0.18 kg.
  Cable: Coaxial MMCX (3-meter integrated cable).

Software; Mobile GPS software for monitoring GPS parameters. Trimble Direct GPS software.

- Computer Mapping software for GIS data capture; Hitachi Software Engineering Co., Ltd. 'MapFolder' with GPS-to-GIS interface.

(b) GPS test runs for position accuracy (Photo 2)

- Time for capturing 3 or 4 satellites: first stage = 9 minutes, second stage = 5 minutes, third stage = 1 minutes.
- Position accuracy (Autonomous): first stage = 47 meters, second stage = 22 meters, third stage = 34 meters.

(c) Merits and demerits of the mobile data acquisition system

- Merits: Light weight hardware system (about 1kg),
- Time and labor saving for GIS data input after reconnaissance.
- Problems: battery usable time is relatively short (about 1.5 hours using simultaneously 2 batteries). Therefore, system needs too much batteries, so it becomes further heavy.
- Invisible LCD screen under daylight.

Photo 1 Mobile data acquisition system.

Photo 2 Field test scene.

Fig. 1 Data Acquisition in Post-earthquake Reconnaissance using GIS/GPS.

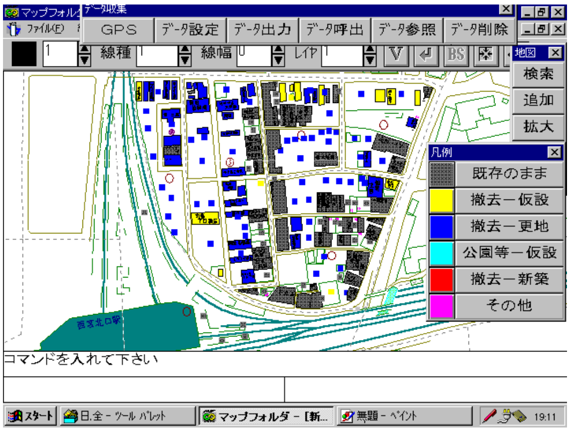


Fig. 2 Screen Display of the mobile system.

GEOLOGICAL CONDITIONS AND DAMAGE DISTRIBUTION OF BUILDINGS AND WATER PIPELINES

Based on the data from Nishinomiya city about various types of the disaster to urban facilities caused by the earthquake, comprehensive analysis has been done. Nishinomiya City is a residential area, where the population is above 420,000 before the earthquake. Figure 3 shows the band of JMA (Japan Meteorological Agency) earthquake intensity VII (severe shaking; equivalent to 9 or more on the modified Mercalli scale). The severely damaged areas of buildings are correspond to the areas of JMA earthquake intensity VII. Nishinomiya City is located at the east end of the disaster band.

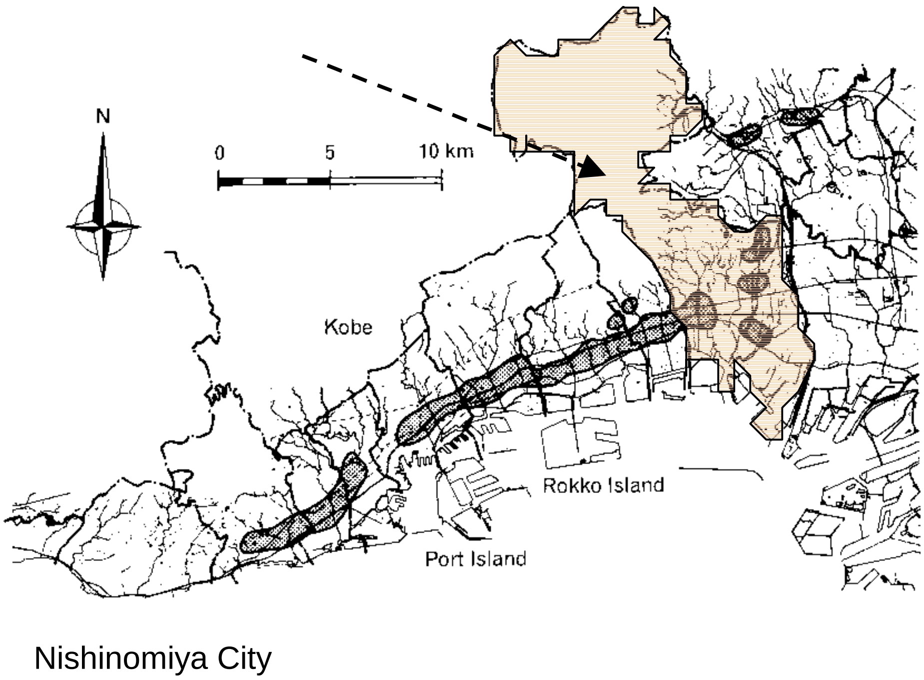


Fig. 3 Zones of JMA (Japan Meteorological Agency) earthquake intensity VII [severe shaking] which is equivalent to X on the modified Mercalli scale.

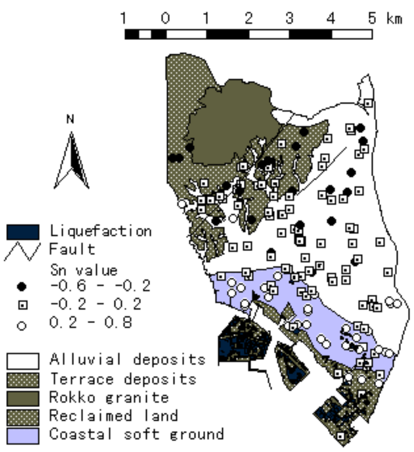


Fig 4. Geological condition and liquefied sites in southern Nishinomiya.

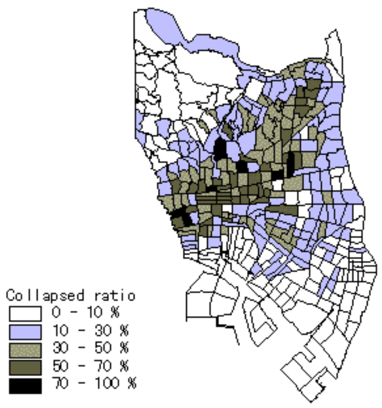


Fig 5. Damage of buildings.

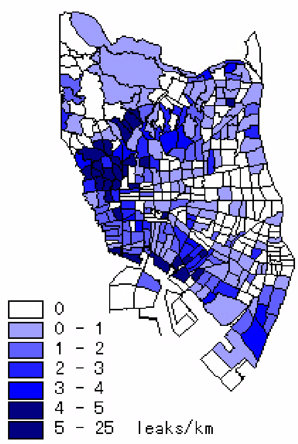
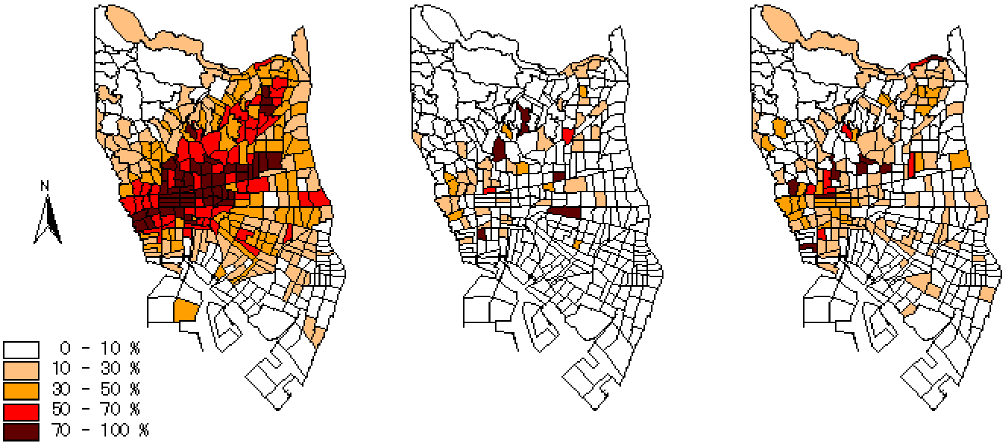


Fig 6. Damage of water pipelines.



(a) Wood houses. **(b) Reinforced concrete buildings.** **(c) Steel buildings.**

Fig. 7 Distribution of collapsed buildings.

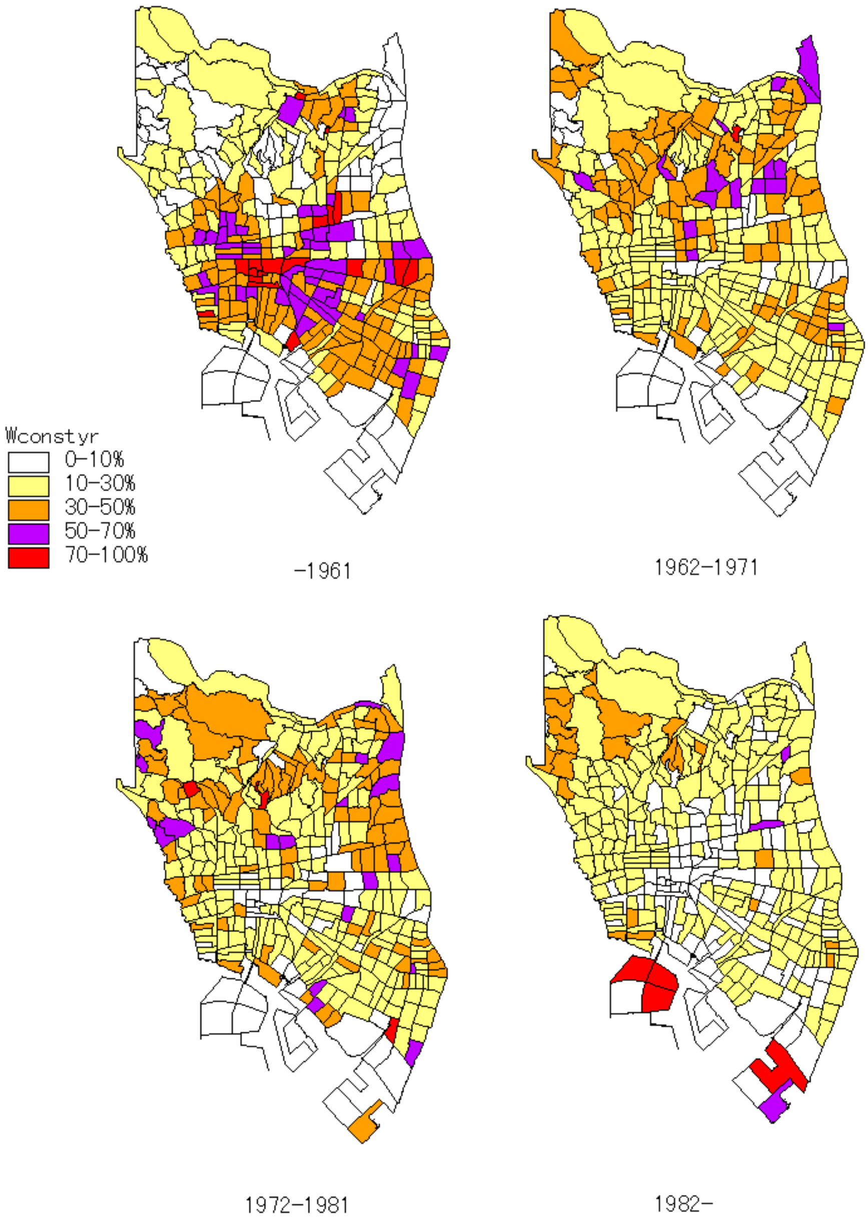


Fig. 8 Wooden house distribution as a function of the construction year.

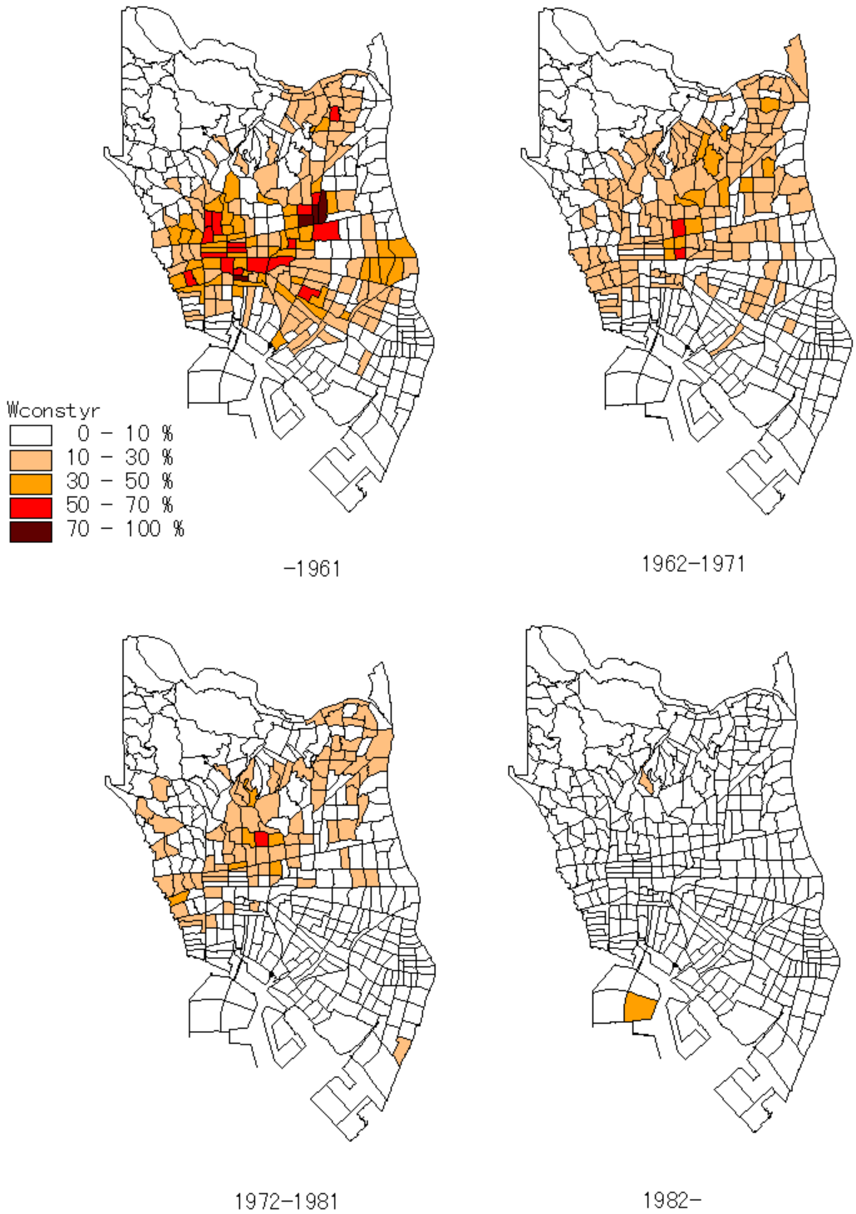
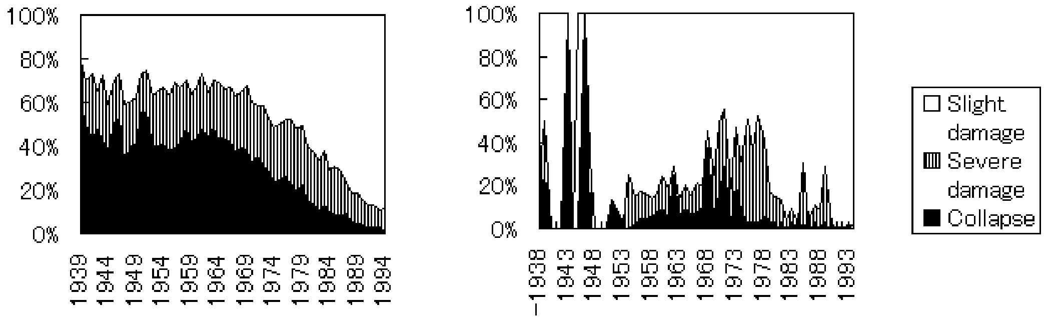


Fig. 9 Distribution of collapsed wooden houses as a function of the construction year.



(a) Wood houses. **(b) Reinforced concrete buildings.**

Fig. 10 Damage ratio for buildings as a function of the construction year.

Correlation studies among geology, ground shaking, ground failure, damage and reconstruction of building, damage and restoration of lifeline, number of persons at emergency shelters and others, should provide an important information for future disaster mitigation and preparedness studies. Some results of understanding are as follows:

1. Comparison of damage distribution of lifeline and buildings (Figs. 4-6): Water pipeline breaks spread out both on coastal soft ground and on boundary field between terrace and alluvial deposits. On the other hand, buildings were severely damaged in the edge field of alluvial deposits near terrace deposits, but they had little damage on coastal soft ground. It is found that damage of buildings was caused mainly by strong ground shaking due to the earthquake, however water pipes were damaged by ground deformation.

2. Lifeline recovery and refugees in emergency shelters: In general, the emergency shelters receiving many refugees located in the area that buildings were severely damaged. However, there were some group of people entered the shelters, whose homes were not collapsed, but had insufficient lifeline supplies. In that case, it is possible to relate between lifeline recovery and decrease of the number of refugees at emergency shelters. Performance-based design of lifeline infrastructure will be needed for faster restoration and reconstruction of peoples' life from disaster.

3. Damage assessment of buildings: The removal state of debris from collapsed buildings is compared with damage assessment by municipal government and exterior damage assessment surveyed by academic organizations. At the selected area which was severely damaged, a half of the "complete collapsed" buildings judged by the city was removed, but the remaining half was not removed. On the contrary, one-forth of the "lightly damaged" buildings judged by the exterior survey was removed. The criteria for building damage assessment and the unified usage are necessary for efficient use of building damage information in the crisis management.

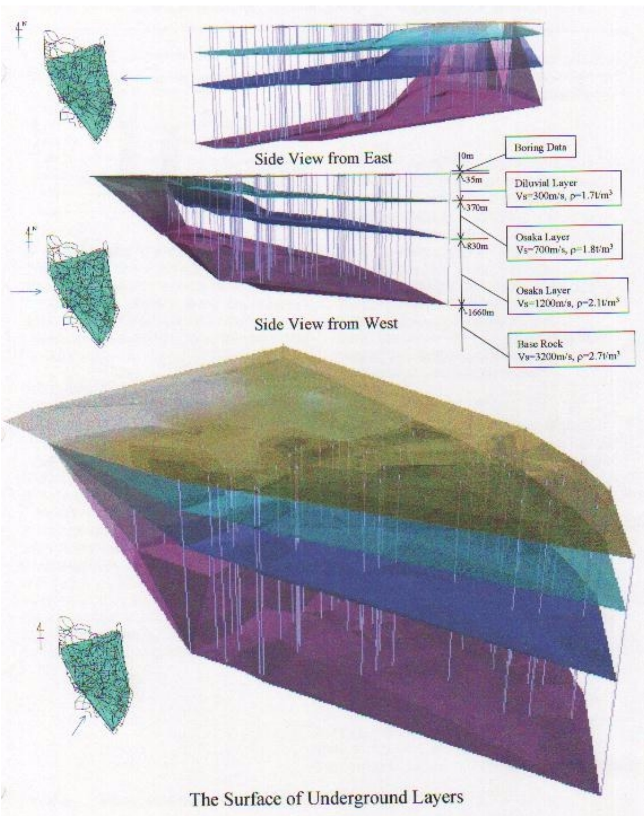


Fig. 11 Assumed underground layers for ground shaking analysis

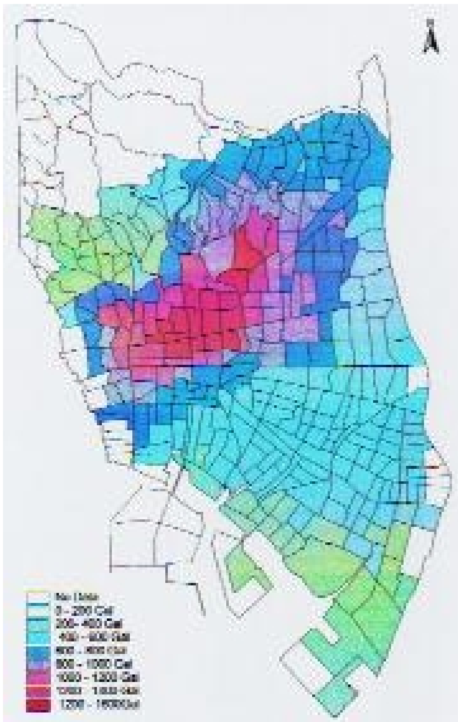


Fig. 12 The calculated maximum ground acceleration distribution.

PRINCIPAL CAUSES INVESTIGATION OF BUILDING DAMAGE

It can be roughly concluded that damage of buildings due to the 1995 Hyogo-ken Nanbu earthquake was caused mainly by strong ground shaking due to the earthquake (Iwai, et al. 1999). Principal causes of building damage were investigated. Using GIS, building damage state was analyzed in correlation to geology, ground failure, building structure and age, and simulated ground shaking. The damage of buildings was strongly related to kinds of structure (Fig. 7) and age (Fig. 10). However, town blocks occupied with many older buildings were not certainly suffered severe damage, comparing Fig. 8 and Fig. 9. Embedded pipelines were damaged by ground failure or deformation, but buildings had little damage on coastal soft ground (see Fig. 5 and Fig. 6). Simulated intensity distribution of maximum acceleration of ground shaking, as shown in Fig. 12 (Shiraki, et al. 1999), based on FDEL (Frequency-Dependent Equivalent Strain for Equi-Linearized Technique) by Sugito (1995) is well correspond to the building damage distribution (Figs. 5 and 7), where the underground layer assumptions (see Fig. 11). The input seismic bedrock acceleration wave was calculated from the measured earthquake waves at Port Island underground 83 meters in depth.

CONCLUSIONS

This study presents post-event data collection system (1) to realize effective methodology to collect urban disaster information in post-earthquake reconnaissance, with combined using of GPS and GIS into mobile computer, (2) to propose useful disaster management tools for emergency response, (3) to apply to rapid assessment and detailed survey of damaged buildings, lifelines and other systems in urban area for risk to second-disaster due to their collapse. Also, principal cause of building damage was investigated. Using GIS, building damage state was analyzed in correlation to geology, ground failure, building structure and age, and simulated ground shaking. The damage of buildings was strongly related to kinds of structure and age. However, town blocks occupied with many older buildings were not certainly suffered severe damage. Simulated intensity distribution of maximum acceleration of ground shaking based on FDEL (Frequency-Dependent Equivalent Strain for Equi-Linearized Technique) is well correspond to the building damage distribution. It can be roughly concluded that damage of buildings due to the 1995 Hyogo-ken Nanbu earthquake was caused mainly by strong ground shaking due to the earthquake.

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