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GIS FOR ASSESSING EARTHQUAKE DISASTER OF TOKYO METROPOLIS

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ABSTRACT: A computer simulation system was developed to facilitate and enhance the engineering decision-making process for earthquake disasters. The present system provides an appropriate platform to examine vulnerability assessments of the water supply network, the road network within congested areas and the highway network. The database with GIS can store and sort complicated network data without difficulty; it enables engineers to comprehensively understand the evaluated results in an easily understood manner.

Key Words: Geographic Information System, Earthquake disaster simulation system

INTRODUCTION

Assessment of potential earthquake hazard is indispensable when the Metropolitan Government is introducing new measures to prevent and mitigate earthquake losses. The Disaster Prevention Council of the Tokyo Metropolitan Government has conducted by simulation an estimation of damages resulting from an earthquake similar in magnitude to the Great Kanto Earthquake of 1923 in 1991 (Disaster Prevention Council of TMG, 1991). In 1997, the Council also conducted experimental research to determine damage estimates for future earthquakes with hypocenters directly below Tokyo (Disaster Prevention Council of TMG, 1997). Although these scenarios provide outlines of disasters, detailed information is required to examine vulnerability of substantial complicated networks. Furthermore, the precise location for earthquake source faults below the Tokyo area has not been exactly determined. These assessments require further case studies in order to correctly identify the variation of damages due to the location of source faults. A computer simulation system was designed to provide an appropriate platform to carry out these assessments (Ogawa and Sekine, 2004).

The GIS disaster simulation system for twenty-three wards within the Tokyo Metropolis was originally developed to meet a variety of needs. The present system has been applied to the following assessments for the Tokyo Metropolitan Government:

(1) Assessment of earthquake-resisting capacity and retrofit program of the water supply network.
(2) Assessment of evacuation difficulty within congested areas of wooden houses.
(3) Evaluation of transportation difficulty caused by damaged bridges and debris of collapsed buildings.

STRUCTURE OF DISASTER SIMULATION SYSTEM

Database Contents

The present system contains the database of thematic maps, choropleth and networks.

Database of Thematic Maps

The database of thematic maps comprises five categories of information as follows:

Geological Information
Geographical Information
Topographic Information
Information about Past Earthquake Disasters
Information about Liquefaction Potential

All relevant information from printed maps is digitized and transformed to raster data by an auto-digitizer. The raster maps are corrected by normalized operation and unified scales from computer processing. Because the topographic information has vector graphics structure, it is transformed to the map of raster graphics structure. Subsequently, all raster maps are compiled according to the Standard Regional Grid and Mesh Code of the Geographical Survey Institute. The unified pixel size is 30"/190 (real length is about 4.86 m) for latitudinal direction and 45"/230 (about 4.92 m) for longitudinal direction. To standardize the regional grid and pixel size, composite maps are compiled by overlay operation.

Database of Choropleth

At choropleth zones, the Chocho-moku quarters are employed in the simulation system. The Chocho-moku quarter is the minimum census tract and the second smallest zone of the address system in Tokyo. The twenty-three wards within the Tokyo Metropolis contain about 3,120 Chocho-moku quarters. The choropleth database enables the number of buildings of each quarter to be identified by story group, structure type, constructed age group, and the daytime and nighttime population of each age group. The building inventory, whose sources are property tax ledgers, has been edited by the Chocho-moku quarters. Using the Chocho-moku quarters, population and building data become easily renewable.

Database of Networks

This database contains the water supply network, the street network and the highway network. Each network is decomposed into nodes and links. Information about locations attributes and topology among nodes and links is stored as tabular data.

System Components and Simulation Flow

The main frame of the simulation system is composed of seven layers as shown in Fig. 1. The evaluation process flows upward from the earthquake source setting of the bottom layer.

The Maximum Earthquake Motion on the Engineering Seismic Bedrock

The maximum earthquake motion is calculated from the earthquake source fault or a hypocenter. These sources can be set arbitrarily. The location of fault and epicenter are inputted by click and drag from the location map within the display. Dip and strike angles and depth and Magnitude are tabular inputs. The maximum acceleration and the maximum velocity are calculated by some kind of attenuation formulae such as the equation proposed by Molas and Yamazaki (Molas and Yamazaki, 1995).

The Maximum Earthquake Motion on the Ground Surface

The maximum motion on the engineering seismic bedrock is converted to that of the ground surface by multiplying the ground amplification factor. Local differences of ground amplification factors are assumed to be the same as the distribution of ground types and are represented by the digitized micro-zoning map compiled from the information contained within thematic maps. The values of ground amplification factors corresponding to the classifications (legend) of the micro-zoning map are set as a tabular data. This zonation is able to set arbitrarily; the assessments described in the paper employ almost the same conditions as the report of the Disaster Prevention Council (Disaster Prevention Council of TMG, 1997)

Liquefaction Susceptibility

Liquefaction susceptibility is estimated from the maximum ground motion at each pixel. The liquefaction susceptibility base map is compiled from the information about liquefaction potential and from geological and geographical information. The tabular threshold values corresponding to the categories of the liquefaction susceptibility base map are arranged to determine the criteria of the maximum ground motions for liquefaction occurrence (Kusano et al., 2001).

Reference of Subsurface Ground Condition

Some earthquake assessments utilize subsurface ground condition together with the seismic ground motion and the liquefaction susceptibility. For the vulnerability estimation of water supply pipes, the evaluation formula uses the coefficient of ground type related to the information (Japan Waterworks Association, 1998). To introduce this information into the estimation, the digitized map is compiled from three kinds of geographical information including that on the past land-use. It is a long held

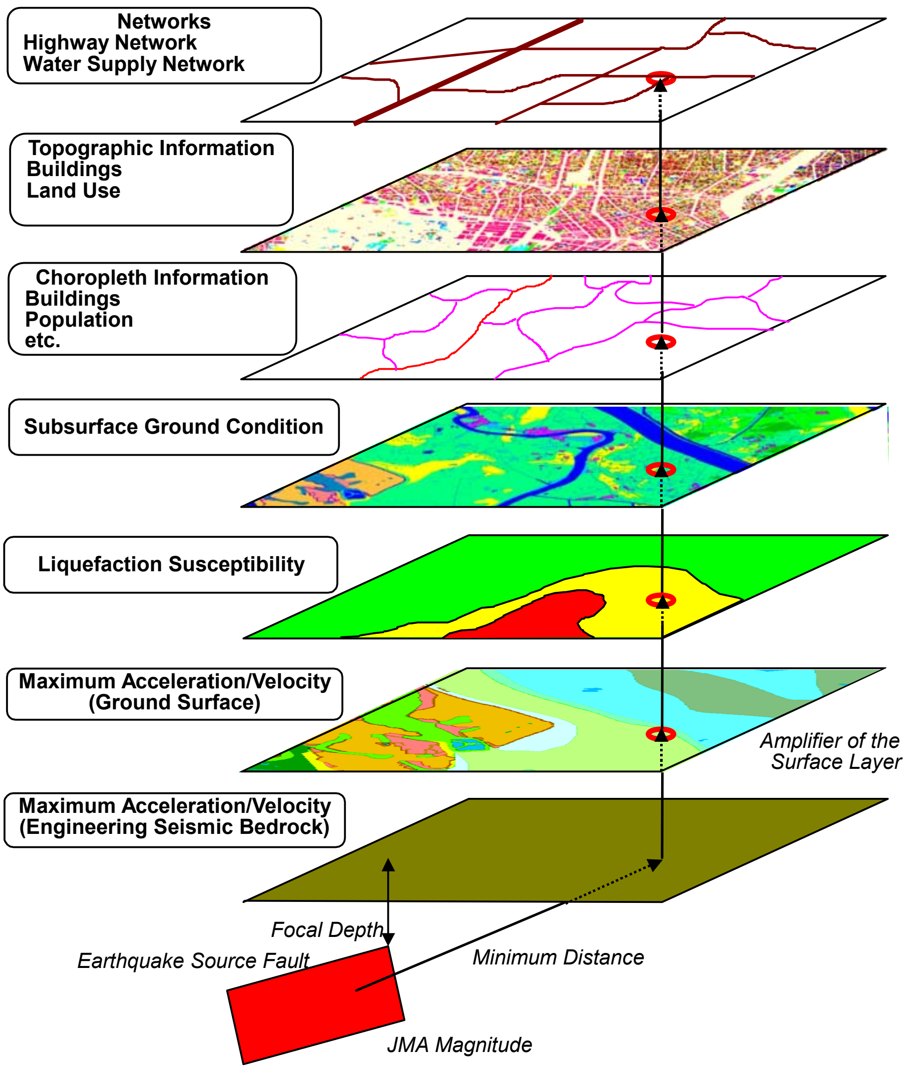

Fig. 1 Structure of the Disaster Assessment Platform

assumption that land-use of cultivation is closely related with subsurface soils.

Damage Estimations on the subject of Choropleth Database

Damages to buildings and victims are estimated in this layer. The sampling points are arranged at regular intervals within each choropleth zone to obtain the variation of the maximum ground motions and the liquefaction conditions. The damage of buildings is evaluated based on the fragility functions with the average of various outcomes by the story group, by the structure type and by the constructed age group. The number of victims at each choropleth is estimated on the bases of daytime/nighttime population and the rate of damaged buildings. The fragility functions of buildings and the estimation formula of victims are similar to the estimation of the Disaster Prevention Council (Disaster Prevention Council of TMG, 1997).

Reference of Topographic Information

Some assessments require neighborhood information to determine the objective malfunctions. For example, transportation difficulty of highways and street-blockades are caused by the collapse of roadside buildings. To evaluate these malfunctions correctly, precise information on building location of buildings is required. The Topographic Information is used in these cases.

For the assessment of evacuation difficulty within congested area of wooden houses, street blockage probability is evaluated pursuant to the formula proposed by Ieda et al. (Ieda et al., 1997). This formula uses the average stories of buildings, density of buildings and the percentage of wooden buildings together with the percentage of total collapse within the roadside area. The former three parameters are calculated derived from the attributes of pixels within the roadside area. The percentage of total collapse is calculated at each choropleth because the attributes of pixel lack information on the construction age. Thereafter, the percentage of each structure type is corrected by the rate of the roadside area to the corresponding choropleth in pixel volume.

The transportation difficulty of highways caused by debris is estimated in an identical manner.

Damage Estimations of Networks

To introduce the maximum ground motion and liquefaction condition to the link of the investigating network from lower layers, sampling points are set along the location vectors of the link. For the assessment of water supply network, the damage of the distribution mains is evaluated on the bases of these values together with the fragility function and the corrective coefficients regarding pipe type and diameter, ground type, and liquefaction susceptibility. The subsurface ground condition is also referred at the same point.

For the assessment of blockage possibility of streets and highways, the contributing area of specified width is located on both sides of the link to evaluate the neighborhood information.

CONCLUSIONS

The GIS disaster simulation system with was originally developed. The system is applied to a series of assessments concerning the vulnerability of water supply network, the evacuation difficulty within congested areas, and the transportation difficulty of highways. The disaster simulation system with GIS is a powerful tool to evaluate earthquake disaster assessments for complicated network systems; and it provides engineers with useful and beneficial information greatly enhancing the future understanding of predicted results.

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