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COMPUTER AIDED SYSTEM FOR ASSESSING LIQUEFACTION POTENTIAL IN TOKYO LOWLAND

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SUMMARY

A computer aided system has been developed to facilitate engineering decision making concerning liquefaction susceptibility in Tokyo lowland. The man-machine interactive system and its graphic display capability not only give an engineer the final evaluated result but also enable him to understand the background knowledge on the factors of liquefaction likelihood. By simply following the menu displayed on CRT, the engineer may be able to easily compare the past land condition with the present one, and to comprehensively understand the subsurface geology and liquefaction potential of the area under consideration.

INTRODUCTION

In order to identify the zones of high liquefaction potentials, it is necessary to have as much information as possible in the area under consideration. The systems engineering procedure is useful for the evaluation of numerous materials collected and for the decision making concerning poorly defined problems such as the assessment of liquefaction likelihood. Information useful for the estimation is translated into the form acceptable by the computer, and man-machine interactive system facilitates engineering decision making.

Tokyo lowland being considered in this study is basically composed of Alluvium. These deposits, including soft Diluvium, range in thickness from 10 m to 60 m. The typical cross section of the ground is illustrated in Fig. 1. On the subsurface, the sandy layer distributes in the range of thickness from 4 m to 10 m and weak as shown in SPT N values being 5 to 10. It is the critical layer for the probability of liquefaction occurring.

The fluvial deposits have formed geographical features known as delta plain, flood plain, natural levee and old river bed on the surface of ground. The landform has been changed according to the development and expansion of the urban area. The landform and the waters in the central area of Tokyo around the year 1460 is illustrated in Fig. 2 (Ref. 1). It can be seen that bogs and marshes were found widespread in the area, but most of them have been filled and flattened up to the present. The land improvements have continuously been done through modern ages with the restoration of the disaster during the Kanto earthquake, the postwar rehabilitation and the large economical growth in the 1960s as momentums. For example, the changes of the waters at or Mukoujima in Sumida ward are shown in Fig. 3. These changes are estimated to have widely been made in Tokyo lowland, therefore the investigation of liquefaction susceptibility involves not only the research into natural ground conditions but also the consideration for the artificial changes of landform.

CONCEPTS OF THE COMPUTER AIDED SYSTEM

Information useful for assessment of liquefaction potential may be divided into the following three categories:

(1) Information about actually liquefied sites during past earthquakes

(2) Information about geography and geology

(3) Information about liquefaction potential based on soil profiles

Type (1) information is most reliable, and therefore this information gives criteria to estimate susceptibility on the basis of the other two information categories. The site where liquefaction has been observed in the past is likely to liquefy again. But it is hard to have records of actually liquefied or not liquefied sites all over the area under consideration, and another information needs to fill the blank areas.

Geographical information includes land condition map and land-use classification map. Old topographic maps facilitate the understanding of landform changes during the past several tens of years. This information is given all over the area under consideration. Landform units or legends of each map are classified independently of liquefaction, and therefore the relations between landform units and liquefaction susceptibility must be determined previously. It is another advantage of geographical information that the boundaries of landform are clearly defined. If the probability of a certain landform unit is able to be determined by some ways, the possibility of zones where are classified as the unit can be estimated all over the area under consideration.

Geological information includes thickness of sand layer map and ground water table map since liquefaction occurs in place shallower than around 20 m. Geological information is only qualitative susceptibility information, but it is able to describe the cause of liquefaction occurring.

Liquefaction potential is evaluated by Simplified Liquefaction Analysis using soil profile records. This information can be treated quantitatively, so the comparative studies of past large earthquakes give useful knowledge for the assessment. The fact that the information gives the probability only at the "points" has a disadvantage. Therefore some effective means should be adopted in order to identify the "zones" of liquefaction potential.

As mentioned above, the three categories of information have some weak points individually, but there are the mutual relations among them to make up for the disadvantages. Therefore the system was designed that the assessment can be performed through comparison and combination with the three constituents of the information. For the purpose of this, the system requires the following two major functions:

(1) To analyze the relationships among the three different sources of information

(2) To present various maps and data graphically and to make the assessment interactively

SOURCES OF INFORMATION

The system utilizes the following maps and data for the three categories of information.

(1) Information about actually liquefied sites during past earthquakes

1. Liquefaction distribution map during the 1923 Kanto earthquake; This map was compiled from accounts of reports concerning the hazard and narratives of interview with some 300 persons who had experienced the earthquake in Tokyo. Details of the map is presented in Ref. 2.

2. Distribution map of damaged wooden buildings during the 1923 Kanto earthquake; This map was quoted from the observation by the Geological Survey (1925). Besides the zones of damaged wooden buildings, the ground failure zones are illustrated.

(2) Information about geography and geology

1. Land condition map; The original map was edited and published by the Geographical Survey Institute in 1970.

2. Landform classification map; This map shows the landform beneath the artificially reclaimed layers.

3. Map of the drainage system and coasts around 1460; This map illustrates the landform before land improvements have been made in Tokyo lowland.
4. Land-use classification map in 1880; It is well known that the land-use of cultivation is closely related with the soil of surface layer. The map shows the land-use of cultivation when the urban area has not expanded widely.
5. Map of the waters in 1909, in 1925 and in 1937; To understand transitions of the waters during the past several tens of years, these maps were prepared.
6. Isobath of soft layers map; This map was prepared for the estimation of maximum acceleration on the ground surface.
7. Ground water table map; The map shows approximate depth to ground water that was compiled from over 11,000 boring records.
8. Soil of Artificial surfacelayer map; Soil of artificial surfacelayer obtained from the profile of boring records are plotted at boring sites.
9. Thickness of sand layer map; This map shows the thickness of Alluvial sandy layer as the critical layer for the probability of liquefaction.
10. Distribution of alluvial gravel layer map; In some places of Tokyo lowland, the gravel layer distributes on shallow depth of the ground. This gravel layer is estimated to restrain liquefaction occurring. The map shows the distribution of gravel layer existing less than 5 m beneath the ground surface.

(3) Information about liquefaction potential based on soil profiles

Data on soil profiles were obtained from more than 11,000 boring records, from which indices on liquefaction potential were computed. The liquefaction resistance factor FL and the liquefaction potential index PL calculated by the Simplified Liquefaction Analysis method were adopted as the indices. Details of this method is presented in Ref. 2.

FUNCTIONS OF THE SYSTEM

<u>Standardization of information</u> All the relevant information on maps was digitized by the auto-digitizer, and scales of various maps were unified by computer processing. Then the numeric maps were compiled according to the Standard Regional Grid and Mesh Code of Geographical Survey Institute. The information on soil profiles were translated into numeric codes by hand. The location of boring sites were connected with the numeric maps on the database.

<u>Relationships among the three categories of information</u> As the information was translated into the form acceptable for the computer, it was easily accomplished to obtain the relationships among the information. For example, Fig. 4 shows the relation between the liquefaction distribution map during the Kanto earthquake and the land condition map. It is seen that the landform units such as Marsh, Low fill-up ground on the waters and Reclaimed land are potentially prone to liquefaction. The ratios of the liquefaction potential indices (PL) included in the each unit of the land condition map are shown in Fig. 5. The relation between the liquefaction distribution map during the Kanto earthquake and the thickness of sand layer map is illustrated in Fig 6. The percentage of the liquefied area increases in proportion to the thickness of sand layer. The areas where the thickness of sand layer is greater than 10 m show high possibility of liquefaction.

<u>Graphic display function and man-machine interactive procedure</u> All the maps mentioned above and the liquefaction potential indices computed for available boring sites can be displayed on CRT connected to a personal computer. Some graphic images of map are illustrated in Fig. 7. On CRT, the legends are classified and displayed in colors. The maps showing the distribution of the liquefaction potential proposed by the authors can be also displayed. By simply following the menu displayed on CRT, the engineer may be able to easily compare the past land condition with the present one, and he can comprehensively understand the subsurface geology and liquefaction potential of the area under consideration. In addition to this, the system was designed to store the rank determined by each map and tc compile the assessment from the ranks. Therefore if the engineer needs the specific assessment that fits his purpose, this system enable him to make a decision, too.

ACKNOWLEDGMENTS

The Institute of Civil Engineering of Tokyo Metropolitan Government undertook the investigation of liquefaction susceptibility in Tokyo lowland and published the liquefaction potential map in 1987 (Ref. 3). This report deals with the computer aided system of the investigation. The authors are deeply grateful to Professor Tsuneo KATAYAMA for many encouraging suggestions during the course of this work.

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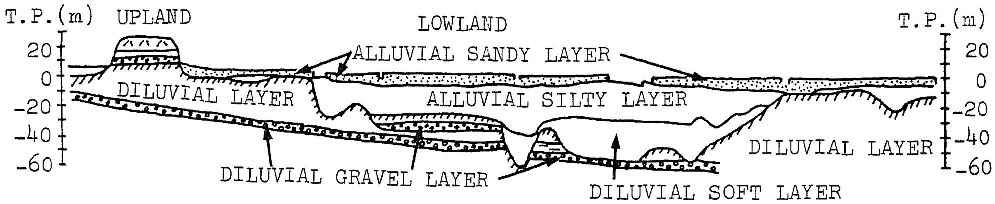

Fig. 1 The typical cross section of Tokyo lowland.

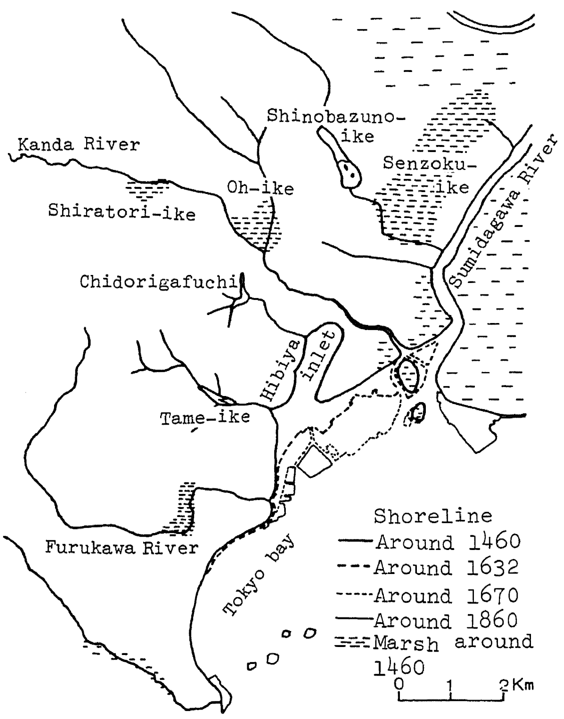

Fig. 2 Map of drainage system and coasts around 1460.

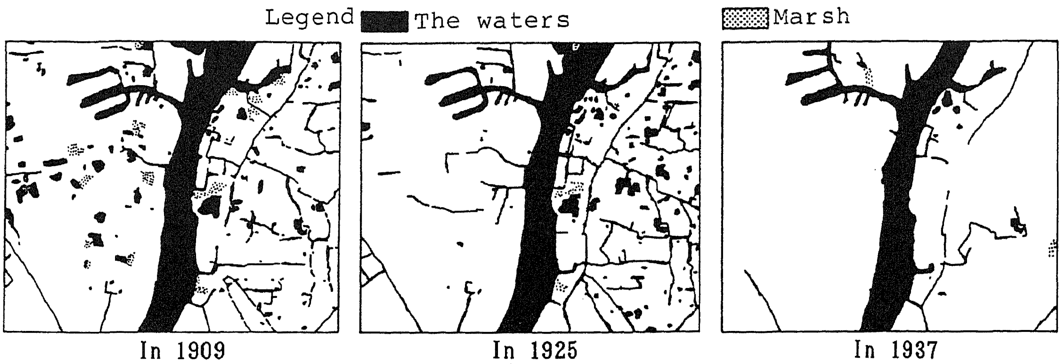

Fig. 3 The changes of the waters during the past several tens of years. (Size of map is around 2 x 2 km)

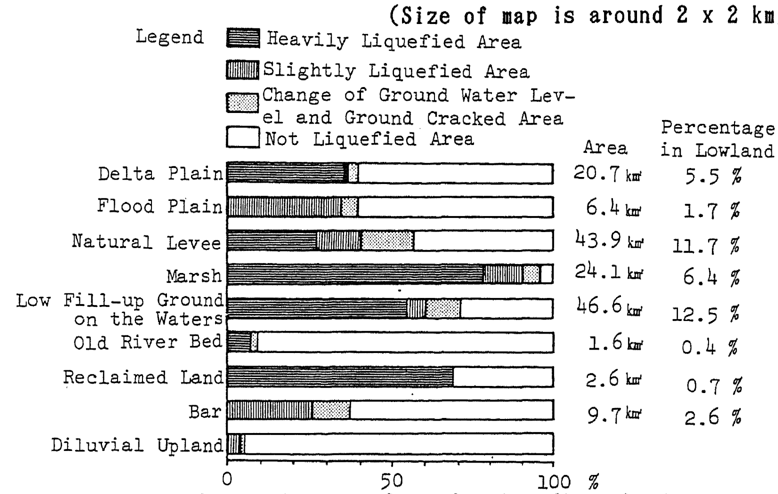

Fig. 4 Relation between liquefaction distribution map during the 1923 Kanto earthquake and land condition map.

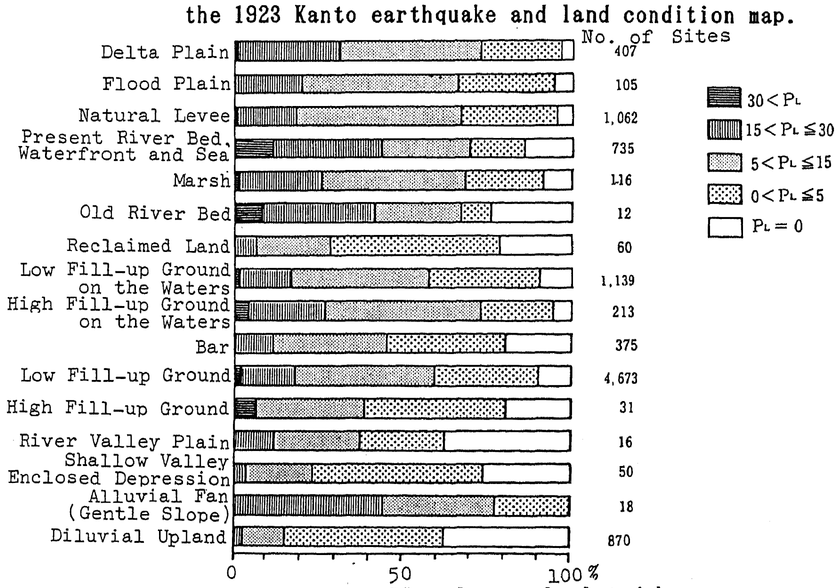

Fig. 5 Relation between PL values calculated by Simplified analysis and land condition map.

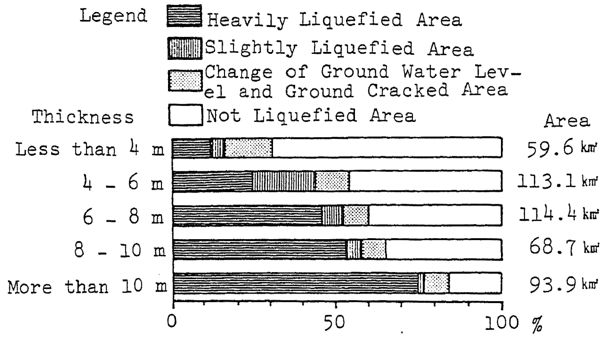

Fig. 6 Relation between liquefaction distribution map during the 1923 Kanto earthquake and thickness of sand layer map.

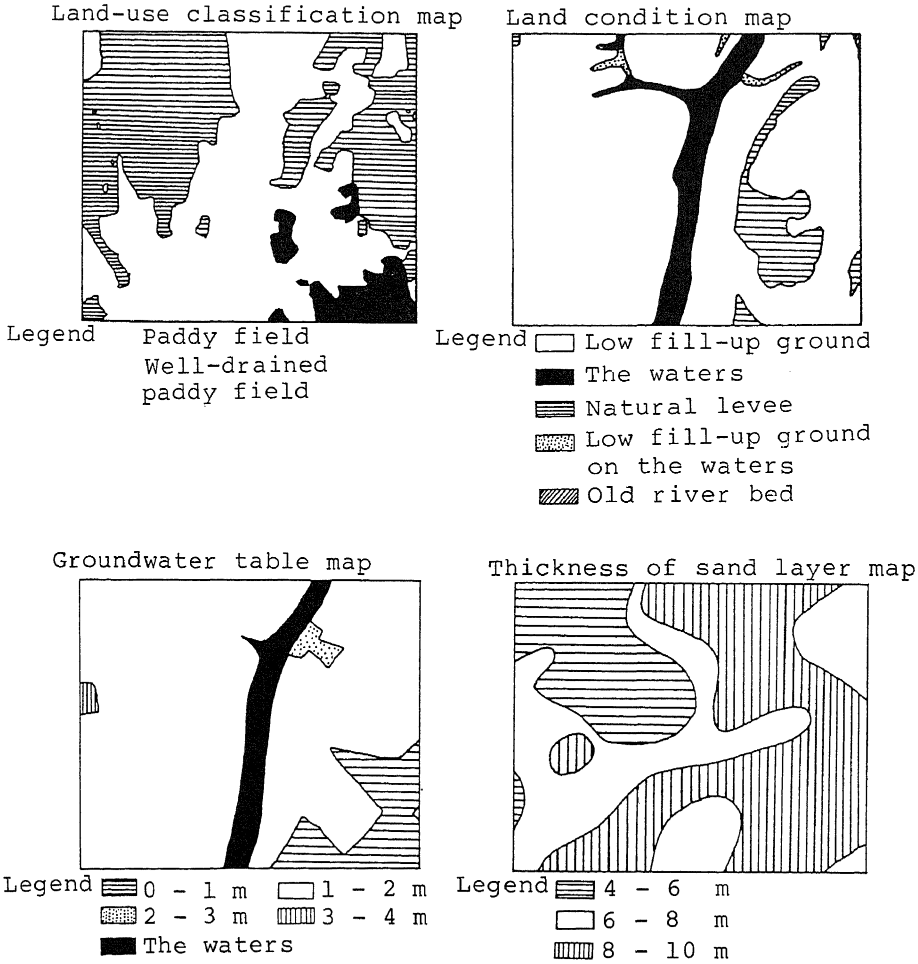

Fig. 7 Some examples of map displayed on CRT.