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RISK OF EARTHQUAKE DAMAGE ON RESIDENTIAL FILL LAND

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SUMMARY

In this study, not only the zonation of the reclaimed bank and cut area but also each bank and cut heights were analyzed in detail from the contour data in the old topographical map before developing and the contour data in the new topographical map of the same place after developing. And latent danger places are extracted at the earthquake occurrence such as the large height bank area and the underground steep slope, which was the ground surface before banking. It became possible that we evaluate quantitatively the cause of the earthquake disaster in the residential fill lands by preparing the classified data of the bank and cut area with new and old elevation value in every each land developed for housing area. For example, the residential fill lands were analyzed around Hiroshima-City, and the topographical features to the earthquake hazards were revealed.

1. INTRODUCTION

In the past, various type of earthquake damages appeared in the residential fill lands. A reclaimed land developed for housing area reaches very serious condition when earthquake damage appears because the nature ground is changed artificially for the weaker residential fill lands in general and the houses are built on it closely. Therefore, many investigations were made to the relations with the damage type of the house and the danger of the collapse of the land developed for housing area itself in every time earthquake damage appears [1], [2], [3]. Especially, it came to be taken importantly after the occurrence of the large-scale collapse damage of the land developed for housing on the hill area in the 1978 Miyagiken-Oki Earthquake (Japan). And, as for the number of damage points related to the residential land area in the 1995 Hyogoken-Nambu Earthquake (Japan), about 5300 places were confirmed in the total such as the collapse of the land developed for housing area, the collapse of the retaining wall and the occurrence of the cracks in the residential land area [4], [5].

There were many types of earthquake damages on the residential fill lands in the 1995 Hyogoken-Nambu Earthquake, theses are classified as follows [2]:

(1) Collapse of slope on the reclaimed bank and cut.
(2) Cracks on the reclaimed bank.
(3) Large scale landslide.
(4) Collapse and Cracks of retaining walls.

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2. INHERENT CAUSES OF EARTHQUAKE DAMAGES IN THE RECLAIMED LAND

As mention above, various type of earthquake damages appeared in the residential fill lands and the large scaled landslide was found frequently. The moving landslide mass scraped the boundary surface, which was formed as ground surface before constructing the reclaimed land. On the other hand, the factors on the damage type of the house were found out by the investigation results on the damaged house due to earthquake on the residential fill lands. There are the distance from boundary of cut and fill, thickness of cutting or filling, original angle of slope under fills and so on [1]. Therefore, the followings are required for the prevision of earthquake damage and the prevention plan.

(1) Total area of residential land, embankment area and embankment volume.
(2) Topographical information before constructing, especially whether there is trough shape or not and its inclining degree.
(3) Average inclining degree of the residential area.
(4) Inclining degree and height of slopes in the reclaimed bank and cut area.
(5) Length and height of the retaining walls.
(6) Construction quality of the artificial residential area.
(7) Kind of the soil and drainage condition.

But almost all these information are scattered and lost, we can’t get now. In this paper, the analysis of new and old topographical map of the same place was employed to get above information (1) to (4).

3. GENERAL FEATURES OF RECLAIMED LANDS AROUND HIROSHIMA-CITY

The construction history of the residential lands around Hiroshima-City is shown in Fig.1. In this figure, 155 reclaimed lands for residence are drawn only, which are lager than 5ha. It can be seen that the area of reclaimed lands are expanded gradually into the hilly and inclined terrain of the weathered granite on the outskirts from the center area of Hiroshima-City. And the area of development for residence becomes lager and lager with the growth of Hiroshima-City. The frequency distribution of the total development area of reclaimed lands, the frequency distribution of the total embanking volume, the frequency distribution of the average height of embankment and the relationship between the average height of embankment and the total development area of reclaimed lands are shown in Fig.2 to Fig.5 respectively based on the data of 155 reclaimed lands. We can see general features of reclaimed lands around Hiroshima-City as follows:

(1) The percentage of the number of reclaimed lands which has the total development area of 5ha or less is 60%, and the number of large scale reclaimed lands which has the total development area of 100ha or more are few.
(2) The number of large scale reclaimed lands, which has the total embankment volume of 1.0×10^6 m^3 or more are few.
(3) Almost all the average height of embankment is 10m or less, it is important to attend that the actual height of embankment is higher than these.
(4) On the relationship between the average height of embankment and the total development area of reclaimed lands, it can be seen that the average height of embankment is decrease with increasing the total development area of reclaimed land. And we can see the closely spread many points in the zone of the very small scale reclaimed lands.

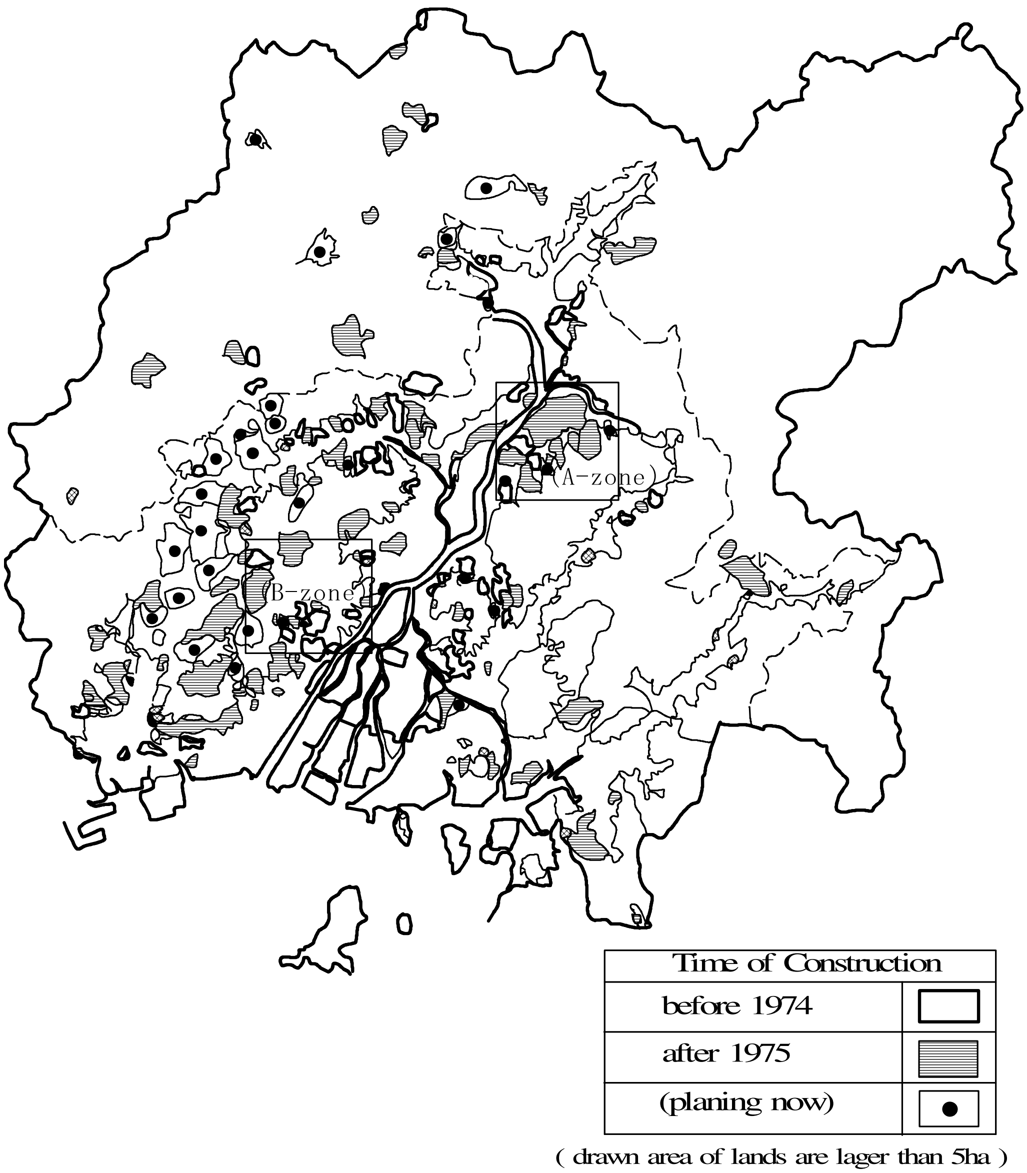

Figure 1: Construction history of the residential lands around Hiroshima-City

4. ANALYTICAL METHOD OF BANK AND CUT HEIGHTS USING THE TOPOGRAPHICAL MAP AND DIGITAL ELEVATION MODEL

As shown in Fig.6, the analysis of bank and cut heights performed based on the contour data in the old topographical map before developing and that one in the new topographical map of the same place after developing. We can get the digital map of the 50m and 250m grid elevation data after developing. These are generated from 1:25,000 scale topographic maps by the Geographical Survey Institute of Japan as DEM (digital elevation model for 250m square mesh and 50m square mesh). But old contour data before developing are not available as DEM. Therefore, the DEM of old contour data before developing were made in this study for the area of the above mentioned 155 reclaimed residential lands.

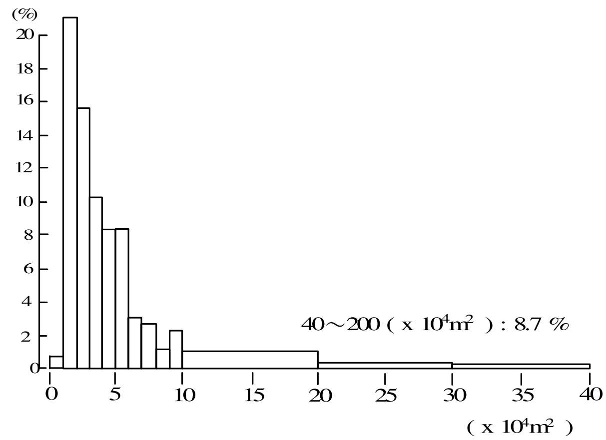

Figure 2: Frequency distribution of the total development area

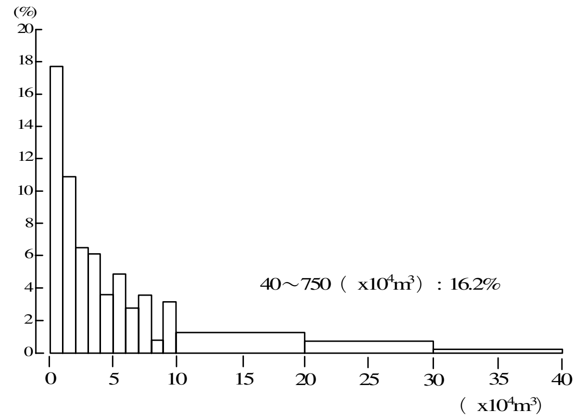

Figure3: Frequency distribution of the total embanking volume

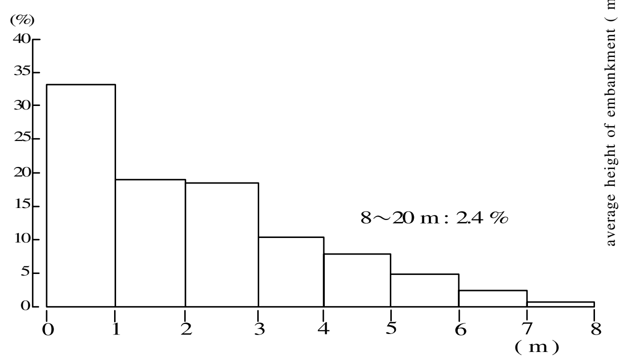

Figure 4: Frequency distribution of the average height of embankment

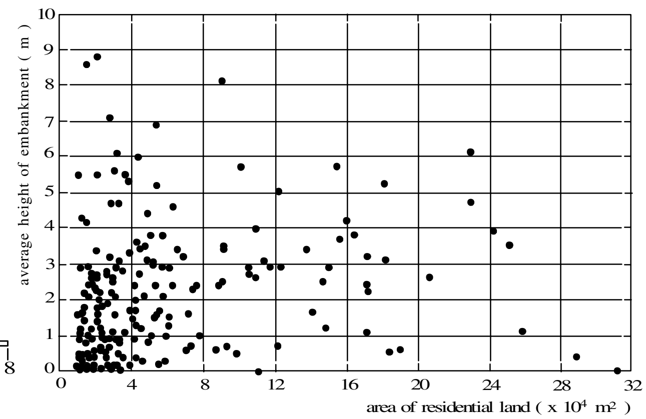

Figure 5: Relationship between the average height of embankment and the total development area of reclaimed lands

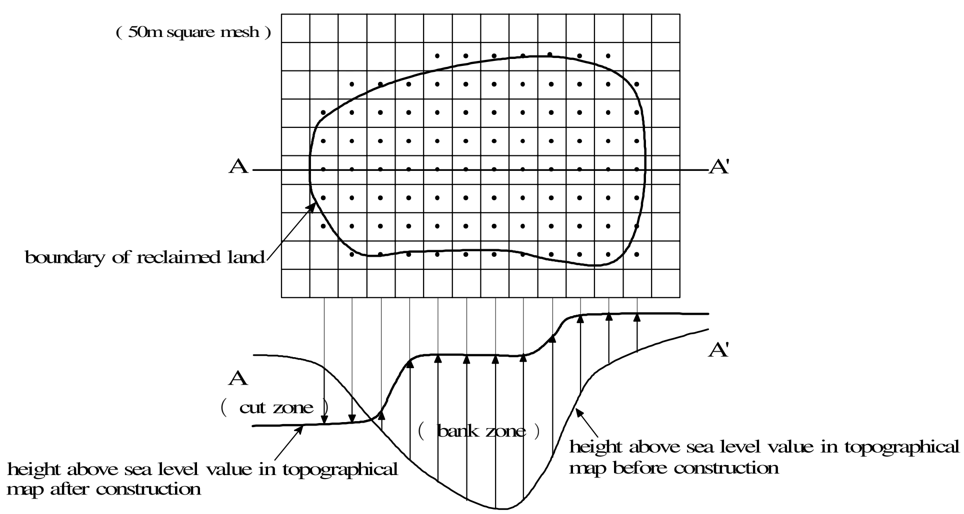

Figure 6: Analysis of bank and cut heights using the topographical map

The procedure of the analysis is as follow:

First, one area of the reclaimed residential land is divided into 50m square mesh, which are same place of the digital map of the 50m grid elevation data generating by the Geographical Survey Institute of Japan. Second, the value of the height above sea level is measured at the center of each 50m square mesh on the old 1:25,000 scale topographic map before constructing the reclaimed residential land, then these digital data are registered on GIS (Geographic Information Systems). As a result, we can analyze the topographical features of old ground surface under reclaimed land and calculate the embankment or cut height on GIS.

5. RESULTS AND DISCUSSION

As shown Fig.7, the maximum embankment height: D_{max} (m), the average inclining degree of the buried valley: S (degree) and the total length of continuously buried valley: L (m) are defined to evaluate the feature of the bank along main buried valley under the reclaimed land. These values are calculated under programming process for the above digital map of the 50m grid elevation data on GIS. The frequency distribution of D_{max} (m), S (degree) and L (m) are shown in Fig.8 to Fig.10 respectively. We can see the features of the bank along main buried valley under the reclaimed land around Hiroshima-City as follows:

(1) Though the average value of the maximum embankment height: D_{max} is about 20 m along main buried valley under the reclaimed land based on the data of 155 reclaimed lands, some reclaimed lands have very large height of the maximum embankment such as 40 to 50 m D_{max}.
(2) The average inclining degree of the buried valley: S is abut 8 degree and the maximum value of S is 22 deg. However, we must pay attention the local place, which has very steep slop along the main buried valley under the reclaimed land.
(3) Though the average value of the total length of continuously buried valley: L (m) is about 300m, some reclaimed lands have very long continuously buried valley of 1000m more over under the reclaimed land.

The damage types of the houses on the residential lands are related to the distance from the boundary of cut and fill, the thickness of filling and the original angle of slope under fills.

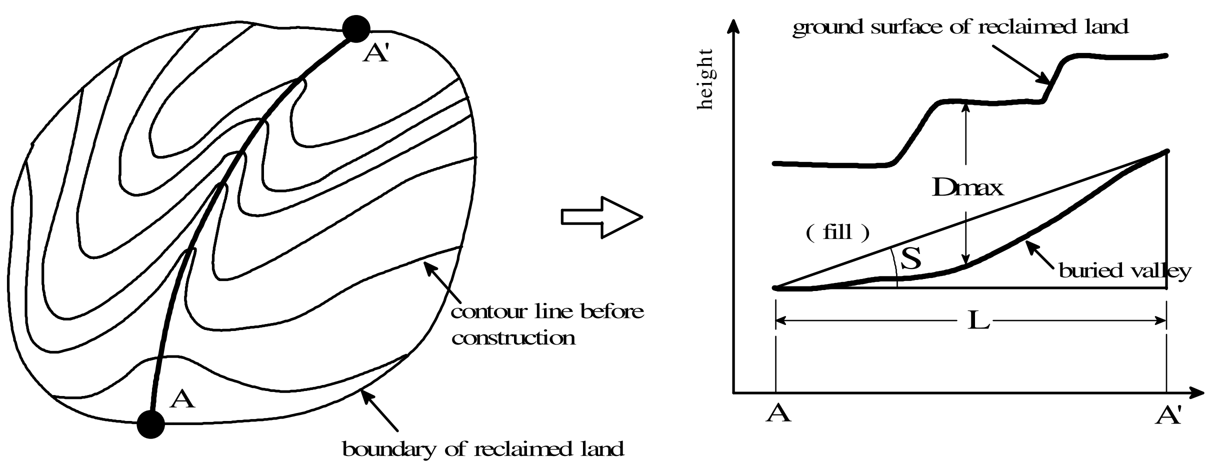

Figure7: Topographical analysis of the bank along the buried valley under the reclaimed land

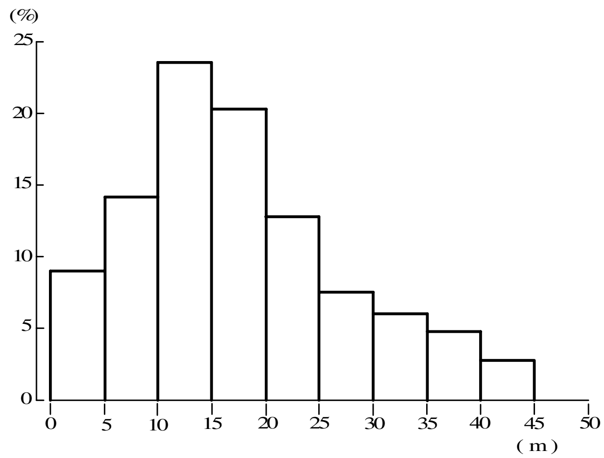

Figure 8: Frequency distribution of maximum embankment height

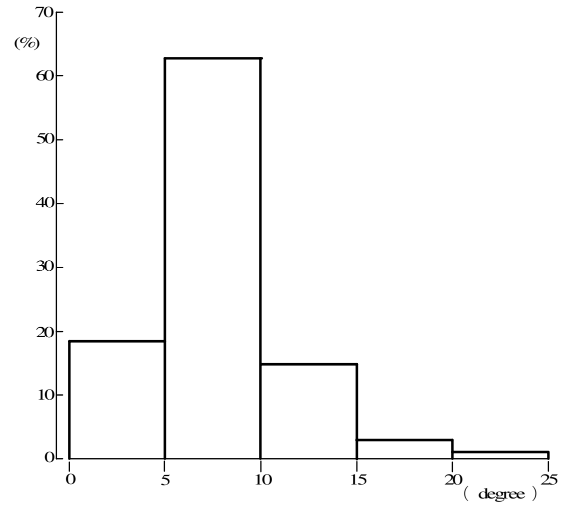

Figure 9: Frequency distribution of average inclining degree of the buried valley

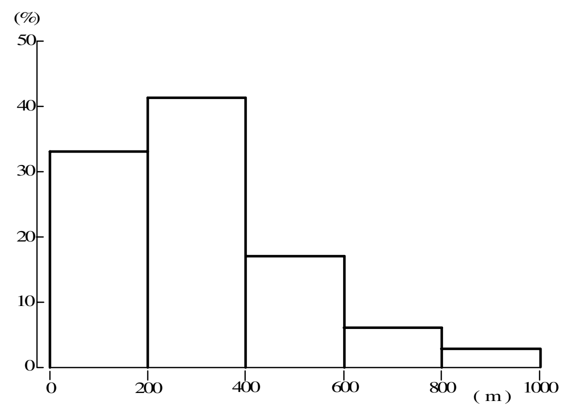

Figure 10: Frequency distribution of the total length of continuously buried valley

Especially, it was found out based on the investigation of the earthquake damages that the damage level of the houses is different clearly between the case of the house on 5m embankment more over and less than. And it is revealed that the damage level of the houses is different with the inclining degree of the buried old ground surface under the ground. Therefore the inherent causes of earthquake damage in the reclaimed land, such as D_{max} (m), S (degree) and L (m) are very important information to predict the earthquake damages of the house with considering the actual earthquake damages.

6. CONCLUSIONS

This paper presents an analytical method to predict the bank and cut heights in the reclaimed residential lands using the topographical map and digital elevation model. And new parameters such as D_{max} (m), S (degree) and L (m) are defined to present the inherent causes of earthquake damages in the reclaimed land under considering the results of the actual earthquake damages. It became possible that we evaluate quantitatively the inherent causes of earthquake damages in the residential fill lands by preparing the classified data of the bank and cut area with new and old elevation value in every each reclaimed residential lands.

The topographic digital data of the residential fill lands around Hiroshima-City are analyzed on GIS to demonstrate the analytical procedure and the results in specific. But the usefulness of the new parameters has not been performed on the actual earthquake damages. It is necessary to make the verification in the future study.

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