THE DETECTION AND EVALUATION OF THE ARTIFICIAL VALLEY FILLIN THE SOUTHERN HILLY AREA OF OSAKA, SOUTHWEST JAPAN

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ABSTRACT

Many hilly area around big cities in Japan, where consists of Quaternary formation, has been developed to residential area since 1960's. These hilly areas are artificially altered with cutting off ridge and valley filling. As the result of the earthquake hazard research, especially, artificial valley fills are clarified its fragility to the strong earthquake motion. However, the distribution of these valley fills and its features at earthquake are not clear.

In this study, artificial valley fills in the southern hilly area of Osaka (Senboku area) are detected by the comparison between the 1960's and the current topographic maps. Additionally, these fills are characterized on the fragility with fill materials (grain size property), surface geometry, and with/without former pond etc. These fragility factors are evaluated for the estimation on the earthquake fragility with GRASS. Thin sandy fills and thick muddy fills are weighted higher on the earthquake fragility due to the liquefaction feature and stability to the strong earthquake motion.

As the result of the evaluation of the artificial valley fill, it is clarified that the fragility of the fills in tributary valley and the stepwise fills are higher than the main valley fills. In the large altered area, the fragility is not high due to the widely surface flattening. It is also clear that several traffic lines, such as a railway line and main roads, across the thick valley fills with large artificial slopes. These thematic maps are available for the countermeasure and city planning to the earthquake hazard.

1. INTRODUCTION

The big cities in Japan are constructed in the Holocene alluvial plains. These alluvial plains develop in the Quaternary sedimentary basin. These hilly areas are located near some main city. Because of this location, hilly area has been developed as dormitory suburb.

Since 1960s, the development of dormitory suburb has been rapidly made progress. Development of dormitory suburb was pushed in hilly area for the preparation of a housing site. These hilly areas made to level ground by cutting from ridges, and filling into the valleys of the hilly area. For this reason, many artificial valley fills are formed in hilly area by the developing.

The 1995 Hyogoken-nanbu Earthquake (Kobe Earthquake) cause damage to the Kobe urbanized area. Many housing areas have damaged, especially, in hilly area that has artificial valley fills. The housing site failured with sliding of fills. It is suggested that the amplification of seismic waves and liquefaction of the soft fill materials contributed to the afflicted areas. For the prevention to the seismic hazard in the fill areas of the dormitory suburbs, we have to clarify fragility factors and these properties.

The Osaka Sedimentary Basin widely distributed in the Plio-Pleistocene hills around the urbanized area. The distribution of such artificial strata, however, is not clearly specified. In this study, the distribution of the artificial valley fills by the comparison between old and current topographic maps is investigated. (Fig.1)

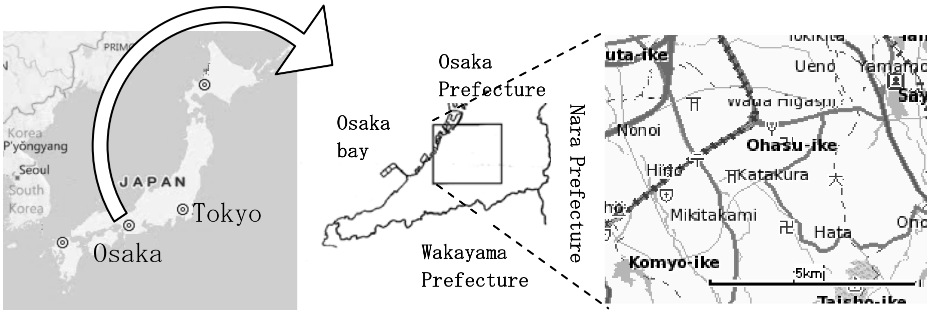

Fig. 1　Location of the Study Area

2. METHODS

Since 1960s, the development of dormitory suburb has been rapidly made progress. So we picked up artificial valley fills by comparing old topographic map with current one. Fig.2 shows flow chart. Comparing old topographic map with current topographic map, we use the aerial photographic survey map of the Osaka Prefecture (scale: 1/10,000; Osaka Prefecture, 1961) and Digital Map 50 m Grid (Elevation) by Geographical Survey of Japan (Geographical Survey of Japan, 1997). The aerial photographic survey map of the Osaka Prefecture is made with the Gauss Kruger projection and Zone VI of Japanese Rectangular Plane on the Tokyo Datum. Digital Map 50 m Grid is made with UTM projection (zone 53N) on the Tokyo Datum. Because two topographic maps is the difference from coordinate, these maps are needed to convert onto same coordinate for overlaying these maps. Artificial valley fills are detected by the altitude difference between old and current maps. After extracting artificial valley fills by comparing two maps, we picked up four factors, such as Thickness of artificial valley fills, Fill materials, Current surface slope angle, Filled ponds. With these four factors, the earthquake fragility of the fills is evaluated with fragility scores. This fragility score distribution provides basic data on the earthquake hazard map. The large slopes on fills that contribute the factor on ground failure at earthquake are also described on the fragility score distribution map.

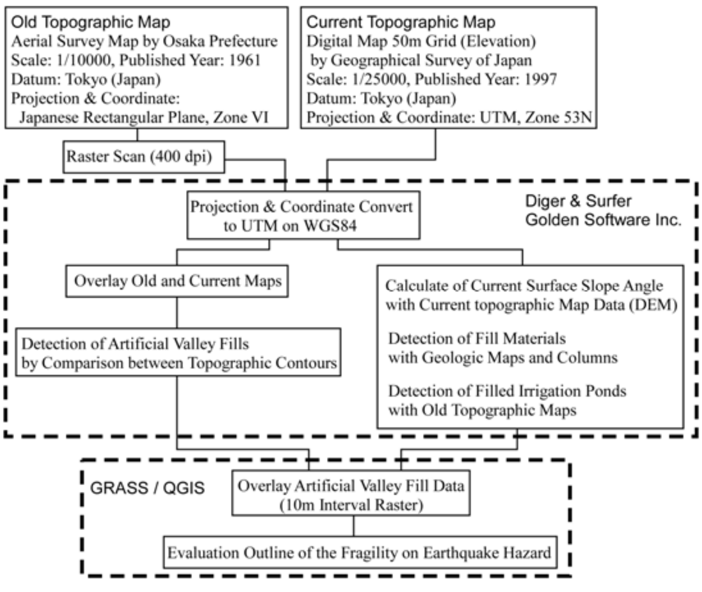

Fig.2　Flow Chart of This Study

2.1 Thickness of the valley fills

The former valley has been filled up earth materials from the former ridges. Artificial valley fills are detected by comparing old topographic map with current topographic map. Thickness of the valley fills are measured altitude difference. The thickness of the valley fills are divided into four stages, such as. less than 5m, 5~10m , 10~15m , more than 15m.

2.2 Fill materials

Fill materials are evaluate with the rate of sand and gravels from the Quateranry formation in the surrounding areas. Yoshikawa (1973) described the detail stratigraphy of this study region. The rate of the sand and gravels are evaluated with the rate of the thickness of layers to the total thickness of layers between the maker beds (marine clay beds). Fill materials are divided into sandy materials (the rate of higher than 50 %) and muddy materials (less than 50 %).

Between the Ma1 bed and the Ma4 bed, the rate of sand and gravels is low (30 % to 40 %). This horizon is the origin of the muddy fill materials. On the other hand, the horizons below the Ma1 bed, and above the Ma4 bed, ranging the rate from 70 % to 80 %, are the origin of the sandy fill materials

2.3 Current surface slope angle

The steep slopes have been failured at earthquakes due to the strong motion, liquefaction, sliding, and toppling. Steeper slopes of fills are unstable at earthquake (Geographical volunteer, 1995).

The slope angle at each point is estimated to the direction of steepest decent on the surface with following expression (1).

$$\|\vec{g}\| = \frac{360}{2\pi}\tan^{-1}\sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2} \qquad (1)$$

（$\partial z/\partial x$ …Variation of east and west, $\partial z/\partial y$ …Variation of north and south）

Thus, the slope angle at each point is expressed in degree from 0 (horizontal) to 90 (vertical). the current surface slope angle is divided into six stages, such as less than 2° , 2°-4° , 4°-6° , 6°-8° , 8°-10° , more than10°.

2.4 Filled ponds

In this region, many irrigation ponds are constructed in hills. In the development, many ponds in the hills are reclaimed with the artificial valley fills. The soft pond sediments act the cause to the liquefaction hazards (Mitamura, 2003). We traced and digitized filled up irrigation ponds described in old maps.

2.5 Artificial slope

The artificial valley fills was formed by cutting hills and filling valley. The marginal slope of fills is made at the threshold of a valley (Fig.3). This artificial slope is almost small scale, so topographic map on small scale does not describe enough. These artificial fill slopes are recognized as the fragile zone on ground failure at earthquake.

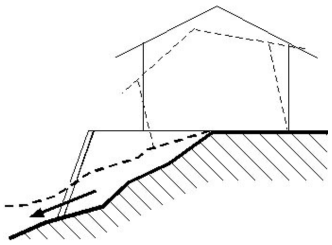 

Fig.3 Example of Artificial Fill Slope
The Slope Failure Pattern (left),
A Photograph of the House on the Fill Slope (right)

We surveyed where artificial slope exist in the study area. In the study area fill slopes are divided into four types, such as grass covering type, stone retaining wall, concrete block retaining wall, concrete gravity retaining wall. We describe these fill slope without the concrete gravity retaining wall as the hazardous sites on the ground failure at earthquakes.

3. RESULTS

3.1 Thickness of the valley fills

The areas of the valley fills are 1415 hectares and the area rate to the development region is 46.7%. In the Senboku Hills, thick valley fills less than 10 meter occupy 80% in all artificial valley fills. And artificial valley fills less than 10 meters thick exist marginal of hills. On the other hand, thick artificial valley fills generally distribute along the trough line of the former main valley in the eastern part of the hills. Especially, the thick valley fills are widely distributed in the north side of the Komyo-ike.

3.2 Fill materials

The sandy fill materials occupy about 80% in whole about artificial valley fills. And the muddy fill materials mainly distribute in the southern part of the Senboku Hill.

3.3 Current surface slope angle

The current slope angle in any development areas is almost gentle. The slope angle of more than 90 % fill area is less than 6 degrees. This result suggests that the former hilly areas altered to the level ground for the housing sites.

3.4 Filled ponds

There are 390 filled up ponds in the study area, filled ponds are widely scattered in this region.

3.5 Artificial slope

Artificial slope is also widely scattered. But, large artificial slopes are located along main road and railway. Some of housing site exists on artificial slope on the valley fills.

3. EVALUATION OF FRAGILITY AT EARTHAUAKE

Table.1 Fragility Scores on Each Items

Item	Category	Fragility Score	
		Sandy Fill Materials	Muddy Fill Materials
Thickness of Fill	15 m and above	0.25	1.00
	From 10 m to 15 m	0.50	0.75
	From 5 m to 10 m	0.75	0.50
	Less than 5m	1.00	0.25
Filled up Pond	Distribution	0.50	
	Non-distribution	0.00	
Current Slope Angle	10 degree and above	1.00	
	From 8 to 10 degree	0.80	
	From 6 to 8 degree	0.60	
	From 4 to 6 degree	0.40	
	From 2 to 4 degree	0.20	
	Less than 2 degree	0.00	

Kamai and Shuzui (2002) investigated and compared the behavior of fill deformation at the former earthquake disasters. At the 1978 Miyagi-ken-oki Earthquake, thick fills were deformed in a high percentage. On the other hand, thinner fills were deformed in a high rate at the 1995 Hyogo-ken-nanbu Earthquake. These examples have a difference in the fill materials. It is thought that the differences of the properties of fill materials are important on the behavior of fill deformation. The detected and evaluated items mentioned above, such as fill thickness, materials, distribution of reclaimed ponds, and the current slope angle, are important factor on the fragility of the housing grounds at earthquakes. As the preliminary evaluation, we estimated the distributions of these factors at each 10 meter interval grid by point method with evaluation score showed in Table 1.

These factors are overlaid and summed with these scores by GRASS/QGIS. After this operation, the total scores are reclassified into four fragility ranks such as 0.20-0.50, 0.60-0.75, 0.80-1.00, and 1.05-2.50 in ascending order. Fig. 4 shows the distribution of the fragility ranks in the study area.

The fragility at the mud fill materials is lower than the sandy materials, because the thickness of fills almost thin (less than 10 meters). The distribution of higher scores is located along the main valley of the margins in the development area.

5. CONCLUSIONS

The result of the detection on the artificial valley fills leads to the following conclusion.

In this study area, the current surface slope angle is low degree (almost less than 6 degree). Almost half area to the development regions in the study area is the artificial valley fills. The fills less than 10 meter thick account about 80%.

The fills of less than 10 meter thick along the main valley correspond to these stepwise housing sites. The thickness of the fills in the flattened upper part of the hill depends on the relative relief of hill.

The fragility at the mud fill materials is lower than the sandy materials, because the thickness of hills almost thin (less than 10 meters). The higher scores more than 1.05 disproportionately distributes in each portion. The distribution is located along the main valley of the margins of the development area and along the margins of the uplifted area of the Plio-Pleistocene.

Artificial slope almost exist along railway and road. At earthquake, if this artificial slope is broken, main traffic lines will not be available for rescue and transfer just after earthquake.

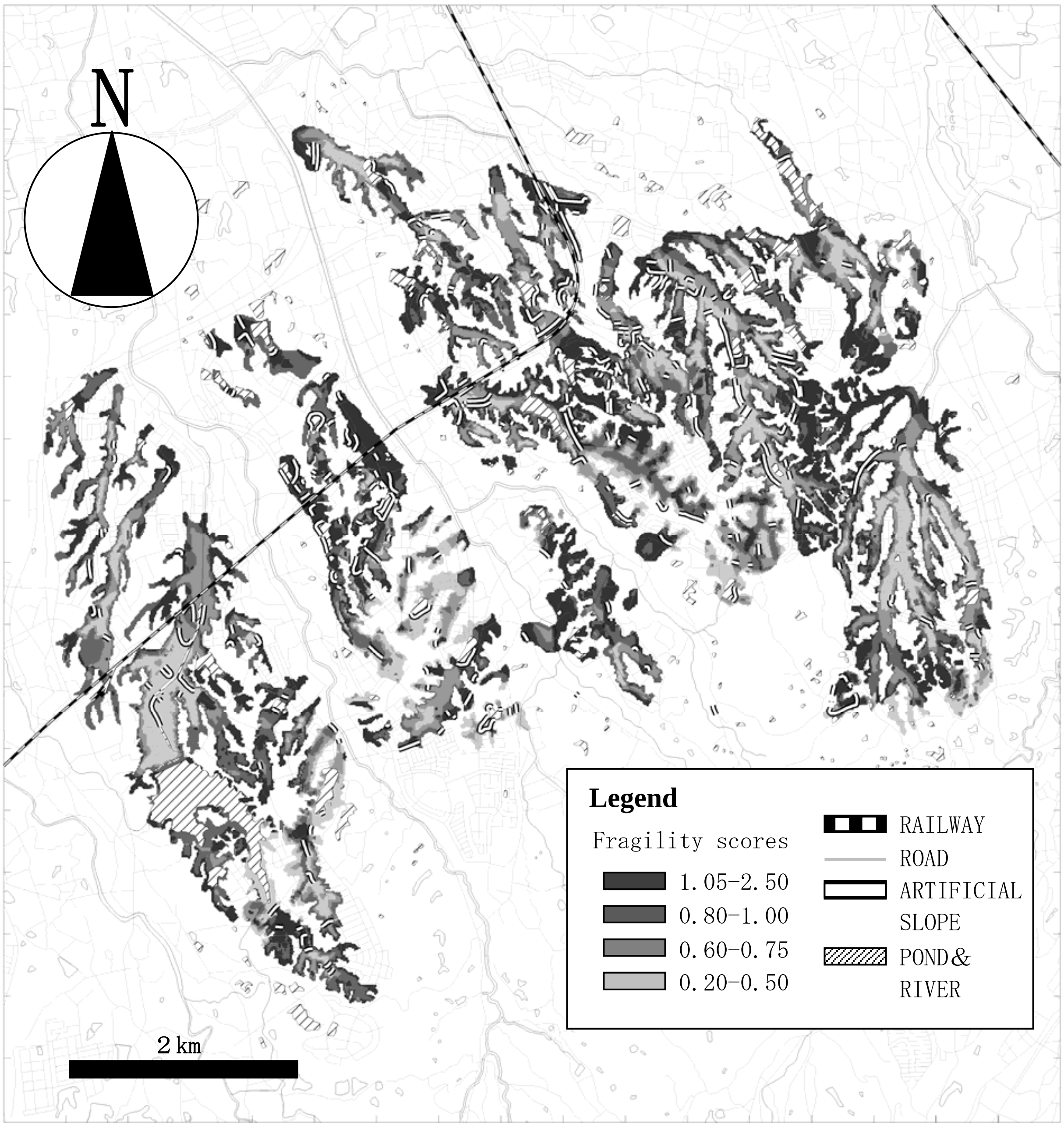

Fig.4 Distribution of Total Fragility Scores of the Fills and the Location of Artificial slopes

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