CORRELATION BETWEEN DAMAGE TO BUILDINGS AND LANDFORM IN THE 1995 HYOGO-KEN NANBU EARTHQUAKE

—An analysis by the application of GIS —

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1. Abstract

The 1995 Hyogo-ken Nanbu Earthquake occurred in January 1995 brought the biggest damage in the years after the World War II to human beings and tremendous damage to buildings.

The Geographical Survey Institute has implemented landform classification in this earthquake at large scales from the perspective of correlation between damage to buildings by the earthquake and landform (ground) and verified by the analysis using GIS (Geographical Information System.)

Key words:

The 1995 Hyog-ken Nanbu Earthquake
land condition
GIS (Geographical Information System)
Landform classification and damage to buildings

2. Introduction

The Geographical Survey Institute has implemented surveys on land condition since 1960 and has produced land condition maps for the objective of providing basic materials such as natural condition on lands needed as counter-measure for disaster prevention and the planning of land use and development.

In particular, from the damage survey in The 1964 Niigata Earthquake, correlation between land condition and earthquake damage was observed, and usefulness of land condition maps have been evaluated in earthquake disaster.

For instance, depending on the period of sediment of the ground and its materials, there was difference in the value of amplification of seismic movement, and the ground which was newly formed and composed of materials of fine grains was likely to suffer bigger damage.

The objective of this survey was to quantify much data by computer analysis to verify the tendency which had been pointed out to be applicable in this earthquake.

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3. Content of the survey

3-1 Extent of the survey

The survey areas were the piedmont of the Rokko mountains which included Takarazuka City, Nishinomiya City, Ashiya City, and Higashi-Nada Ward, Nada Ward, Chuo Ward, Hyogo Ward, Nagata Ward and Suma Ward of Kobe City which were located in the northwest side of the Bay of Osaka. In consideration of topographic characteristics and state of damage, six map sheets at a scale of 1:10,000, such as "Takarazuka," "Ashiya," "Nishinoiya," "Rokko Island," "Sannomiya" and "Nagata" were designated to be the survey areas. The positions of the survey areas are shown in Fig.-1.

3-2 Materials for the survey

In this survey, such materials were used as Damage distribution map of The 1995 Hyogo-ken Nanbu Earthquake (the Second Version) which was produced by the urgent survey implemented after the occurrence of the earthquake, and provisional topographic map at a scale of 1:20,000 in Meiji Period and land condition map at a scale of 1:25,000 and reports made from 1984 to 1986.

The list of materials used in this survey is shown in Table-1.

3-3 Establishment of Survey Committee

For this survey, Survey Committee composed of members from academic societies was established and discussion was made on the contents to be indicated in the land condition map from the perspective of earthquake disaster prevention and details of analysis on landform and damage to buildings. The members of the Survey Committee are shown in Table-2.

3-4 Survey

The major objective of this survey was to study on the composition of land condition map which was applicable to disaster prevention assessment such as earthquake disaster, and to find out causes and effects on correlation between landform and damage to buildings in The 1995 Hyogo-ken Nanbu Earthquake by the application of the methodology of GIS. Flow of the survey is shown in Fig.-2.

4. Composition of land condition map and data digitization

4-1 Composition of land condition map

Composition of land condition map is shown in Table-3. It is composed of "landform classification" which indicates form and characteristic of land, "contour of ground elevation" which describes elevation of lowland from the sea level, "landslide" which indicates slope failure occurred by the earthquake and "disaster status" which indicates the status of collapse and damage to houses and buildings, fire, and liquefaction of ground.

In landform classification, former landform was classified and indicated in order to identify the initial form of artificially deformed area.

In particular, to add value for the application of disaster prevention assessment such as earthquake disaster prevention, next four items were introduced in the items of expression.

1) Landforms after the change were indicated by additional symbols on the indication of former forms of the artificial change, such as mountain slope, valley plain and terrace.

2) Also in banked up surface in lowland, banked up surface after the change was indicated by additional symbol on the indication of former forms, such as valley plain or flood plain, coastal plain or delta, back marsh, former river bed and sea area.

3) Former shoreline, pond, marsh and drainage system were restored and overlaid on the present landforms.

4) Break lines of slopes (convex break and concave break) were indicated.

4-2 Data digitization

Data collected in 3-2, result of photo interpretation and landform classification made by reconnaissance survey were digitized, and data base was made. GIS which has functions of data analysis, data indication, data retrieval and data output was used for data digitization.

Systems used for data base production are:
EWS: Sun Micro Systems
OS: Solaris ver 2.4
Application: ARC/INFO ver. 7.0.4

Functions with frequent use were studied and selected from the basic functions of ARC/IFO, and programming was made by ARC/INFO micro language AML.

Based on this, all the data which were collected in 3-2 were digitized and stored in each hierarchy as indicated in Fig.-4

4-3 Production of land condition map

Without using traditional production process, land condition maps were produced by the computer by digitizing all the information.

They were produced in the following process. Land condition data and disaster status data, which were the major information for land condition maps, were input by scanning, and ARC/INFO coverage was made. It was stored by Graphics, a standardized file for output of ARC/INFO, as each delineation information, such as color, size and indication system, and various format conversions and ornaments were made, and output was made as land condition map at a scale of 1:10,000.

5. Analysis and result by the application of GIS

On the study of correlation between landform classification and damage to buildings, means of interpretation was changed from traditional visual interpretation to quantitative interpretation by computer processing. Data base of landform classification, land slide, former landform, ground elevation and collected data were analyzed in various forms using ARC/INFO's data retrieval, and data analysis and totaling functions.

Analysis was made in three items shown below.

1) Relation between damage to buildings and land condition (landform classification) and former land use

2) Relation between land slide in the Rokko Mountains district and elevation, slope, slope azimuth and convex break of slope

3) Relation between ground liquefaction

and land condition and former land use
In this survey area, there were remarkable damage to buildings in Ashiya City where analysis of similar items on the damage to wooden buildings was made.

5-1 Damage to buildings and landform

Analysis shown in Table-5 was made to find out the relation between damage to buildings and land condition, and correlation was found out by the quantitative interpretation.
Schematic view of the landform from the mountain side to the sea in the survey area is composed in order of terrace, alluvial fan, gentle frontage of fan, flood plains, valley plain, coastal plain, delta and sea. Landforms of sizable area, such as lowland, relatively higher and well drained and shallow valley on terrace appear as well.
Size of land with damage to buildings in the area was plotted as area of damage to buildings on disaster status map and overlay was made according to land condition and former land use, and total area was summed according to the scale of damage.
Based on this, the area ratio of damage to buildings shown in Fig.-3 was found out.
The ratio of damaged district in each landform classification of land condition was found out by this ratio and that of gentle frontage of fan is the highest and alluvial fan follows. It is observed that there is a peak in gentle frontage of fan and decrease of damage is seen towards both of sea and mountain side. This overlaps for the most part with the arrangement of zone of the earthquake disaster at the southern piedmont of the Rokko Mountains which is indicated as the district hit by a JMA intensity scale of 7.
On the analysis of damage to buildings in Ashiya City, data of respective wooden buildings were extracted from the digital mapping data prepared by the city and their state of damage was read from the distribution map of damage level of buildings (the Building Society) and analysis was carried out. The result is completed in Fig.-4.
Damage was especially concentrated in Ashiya City where 6,937 units were damaged including 270 badly damaged, 1,470 medium damaged and 4,257 slightly damaged, which are 60.5% of wooden buildings out of 11,458 units in the area of object.
In the same way as stated above, the ratio of units of damaged buildings was found out according to landform classification and former land use.
In landform classification, the biggest damage is observed in gentle frontage of fan and decrease of damage is seen towards mountain side in order of alluvial fan and terrace. In lowland, bigger damage is observed in coastal plain or delta and smaller damage is seen in valley plain or flood plain.
In former land use, damaged buildings are distributed equally in each category of use both on all survey areas and Ashiya City.

5-2 Slope failure

Collapse occurred in this earthquake was observed in 248 positions in five sheets (except for "Rokko Island" as it was not observed) in the survey area. Analysis of slope failure was carried out on elevation, slope, slope azimuth, and position between

convex break of slope and slope failure.
In order to compare with the result of the survey area, separate analysis was carried out on the sheet of "Takarazuka," in which mountainous district occupied 65% of the total area and the biggest number of land slides occurred.
On the grid data of elevation, slope and slope azimuth made from 50 grid data of digital map, position information of land slide was overlaid and the density of the occurrence of collapse was summed up. The result is shown in Fig.-5. Position related with convex break of slope is found out in Table-6.
In the category of elevation, it occurs in the elevation more than 50 to 100m, and the density of the occurrence of collapse per 1km is the highest in the elevation between 300 to 400m. In the category of slope, the density of occurrence of collapse in slope category starts to become high at 20 degrees or more, and the highest density per 1km is observed between 40 to 50 degrees. There were no data for 50 degrees or more, therefore analysis has not been carried out.
In slope azimuth, much more collapse is observed in order of NE, N, E, S in all the survey area, and only for Takarazuka Sheet, it is observed in order of the slope of E, S, SE, and NE.
Concerning to collapse and convex break of slope, 80% of the collapse occurred on the valley side below convex break of slope, and approximately 15% of the collapse, which appeared to make convex break slope recessed, were observed on convex break slope.

5-3 Liquefaction

Former land use map and land condition map were overlaid in the limits of occurrence of liquefaction shown on the map of present state of disaster (the second version,) and the size of the area according to each category was summed up. The flow of summing process is shown in Fig.-6.
In the survey area, size of the area where liquefaction occurred totaled 5.48 km^2 including the occurrence of liquefaction of 5.32 km^2 in reclaimed land, which occupied 97% in total area of occurrence. The size of reclaimed area in this survey was 20.62 km^2 and liquefaction occurred in the area of approximately 26% of it. Fig.-7 shows the size ratio of liquefaction in each category in the sheets on which survey was carried out. Overwhelming majority of the area of ground liquefaction is observed in the category of reclaimed land, and some are found only in the specific landforms, such as gentle frontage of fan, natural levee, sand bank or sand bar, coastal plain or delta and valley plain or flood plain. According to former land use, high ratio of the occurrence of liquefaction was observed in the area which was classified as water area in the topographic maps in Meiji Period.

6. Summary

Clear view of correlation between damage to buildings and landform (ground,) which was the primary objective of this survey, was not found out in this survey area.
However, big damage was concentrated in the area classified as gentle frontage of fan, and much smaller damage was observed towards both sea and mountain sides making the peak in this gentle frontage of fan.
Some instances show that areas which have potential for sufferings, such as slope

failure and liquefaction could be predicted by landform information.
It was found out if land classification was digitized, it would be useful for post facto measures and disaster prevention by prompt simulation and analysis.

References

1. Geographical Survey Institute (1966): "Report on the Survey of Land Condition (Kyoto and Harima area) "and attached map.pp.110. 8 sheets.
2. Geographical Survey Institute (1983): "Report on the Survey of Land Condition (Osaka area) " and attached map. Geographical Survey Institute Technical Materials D・2-No.37, pp.182. 4 sheets.
3. Geographical Survey Institute (1965): "Report on the disaster of the Niigata Earthquake" pp.59. 2 sheets.
4. Takashi Okimura (1995): "Survey on the damage to houses and disaster mapping. Report on the urgent survey of damage of the 1995 Hyogo-ken Nanbu Earthquake (Second report) " Department of Engineering, Kobe University, pp.20-41
5. Shingo Tanaka (1995): "Landform classification between Kobe and Hanshin. Report on the 1995 Hyogo-ken Nanbu Earthquake - geology, ground and disaster" Survey Committee of the Hanshin Awaji Earthquake Disaster Japan, Applied Geology Society, pp.23 - 32
6. Geographical Survey Institute (1995): Damage Distribution Map of the 1995 Hyogo-ken Nanbu Earthquake (the Second version.) 21 sheets
7. The City Planning Institute of Japan Kansai Chapter, The Architectural Institute of Japan Kinki Chater. (1995) : Hanshin, Awaji Earthquake disaster's actual situation urgent investigation The distribution map of damage level of buildings (1995) pp.120
8 The Rokko-Sabou Kouji Office (Erosion Control Work Office for the Rokko mountain area) (1995): The distribution map of new and more spread collapse area (1:10000)

Table. 1 Materials

Provisional Topographic Map 1:20,000 in Meiji Period Ikuse-Mura 1886 Kobe 1885 Nishinomiya-machi1885 Hyougo 1886 Imatsu-mura 1884 Suma-mura 1885 Rokkousan 1186 Material:Geographical Survey Institute
Land Condition Map 1:25,000「Osaka-seihoku-bu」「Kobe」 Report 「Kyoto/Harimachiku」 1966 Land Condition Map 1:25,000「Osaka-seihoku-bu」 Report 「Osakachiku」 1983 Material:Geographical Survey Institute
The distribution map of new and more spread collapse area Material:The Rokko-Sabou Kouji Office Ministry of Construction
Danage distribution map of the 1995 Hyogo-ken Nanbu Earthquake (The second Version) Material:Geographical Survey Institute
Hanshin,Awaji earthquake disaster's actual situation urgent investigate The distribution map of damage level buildings 1995 Material:The committee for reconstruction of earthquake disaster and city planning

Table. 2 Establishment of survey committee

	Name	Authority
Chairperson	Takashi Okimura	Professor,Kobe University
Member	Shingo Tanaka	Professor Emeritus,Kobe University
Member	Masahisa Hayashi	Professor,Shimane University
Member	Kazue Wakamatsu	Visiting Researcher,Waseda University

Table. 3 Contents of Land Condition Map

Landform Classification	Mass-wasting,Unstable slope, Terrace(4 sections), Piedmont aggraded slope(3 sections),Dent or shallow valley Lowland relatively higher and well drained(4 sections), Submersible land surface(2 sections), Water sphere, Artificially deformed area(8 sections), Break lines of slopes(convex,concave), Former drainage system, Former pond,marsh are indicated in all
Contour of ground elevation	Contour at 2m or 4m intervals is indicated in lowland
Land slide	Continuous land slide before the earthquake(2 sections), New land slide by the earthquake, New land slide after the earthquake,Baldness and bare rock
Disaster	Collapse of and damage to houses and buildings(damage level,floors 2 sections each), Limits burnt by fire, Area of liquefaction of the ground

Table.4 A List of Digital Data

Layeres	Data form	Layeres	Data form
Land condition map	polygon	Digital Map (Linear)	line
Deformed area(Additional symbols)	polygon	Digital Map (Altitude)	grid
Former land use	polygon	Land slide by the Rokkou Sabou	polygon
Collapse or seriously damaged	polygon	Contour of ground elevation	line
Slightly damaged	polygon	Convex break of slope	line
Collapse or seriously damaged more than three story building	polygon	Divide	line
		Shaded Map	grid
Slightly damaged more than three story building	polygon	Slope azimuth	grid
		Slope	grid
Fire(burnt area)	polygon	Removed buildings data	point
Liquefaction of ground	polygon	Distribution map of building damage level	point
Digital Map (Rivers)	polygon		

Table.5 Analysis between Damage to Buildings and Land Condition

		Land Condition		Former land use	
		All survey area	Every Map	All survey area	Every Map
Damaged buildings'area	Collapse	○	○	○	○
	Collapse+Slightly	○	○	○	○
	No damages	○	○	○	○

Relation between Wooden Buildings and Land Condition

		Land Condition		Former land use	
		All survey area	Ashiya City	All survey area	Ashiya City
Number of houses of each damage level	Badly		○		○
	Badly+Medium damage		○		○
	Badly+Medium damage+Slightly		○		○
	No damages		○		○
Rate of each damage level of buildings in each land condition	Badly		○		○
	Badly+Medium damage		○		○
	Badly+Medium damage+Slightly		○		○
Rate of each damage level of buildings in each land condition edge	Badly		○		○
	Badly+Medium damage		○		○
	Badly+Medium damage+Slightly		○		○
Distribution of damaged buildings	Badly		○		○
	Badly+Medium damage		○		○
	Badly+Medium damage+Slightly		○		○

Table.6 Positions of Convex Break of Slope and Slope Failure

Convex break line	All survey area		Takarazuka sheet	
	Spot	Ratio(%)	Spot	Ratio(%)
Ridge side	9	3.6	0	0.0
On the line	36	14.5	6	8.7
Valley side	203	81.9	63	91.3
Total	248	100.0	69	100.0

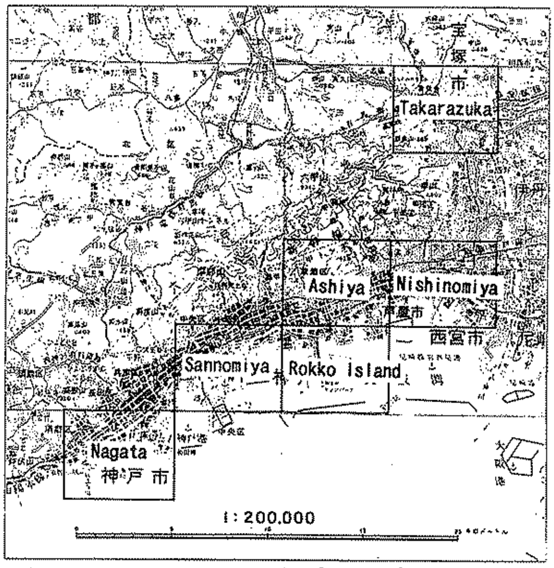


Fig-1 Positions of the Survey Area

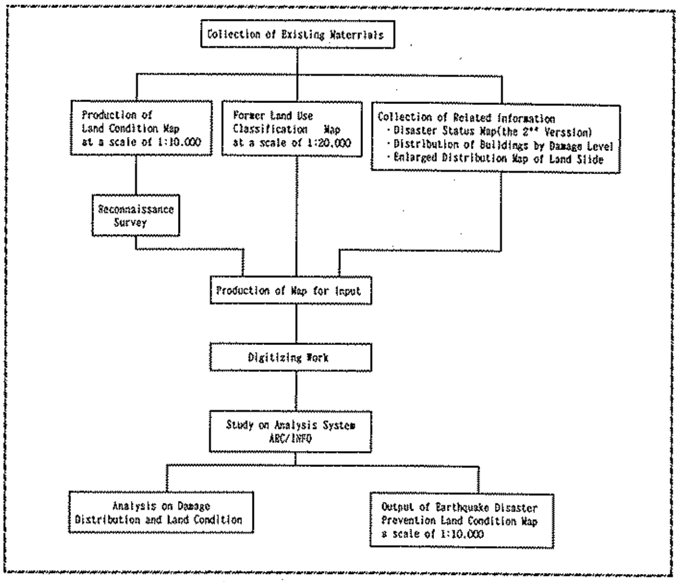


Fig-2 Flow of Survey

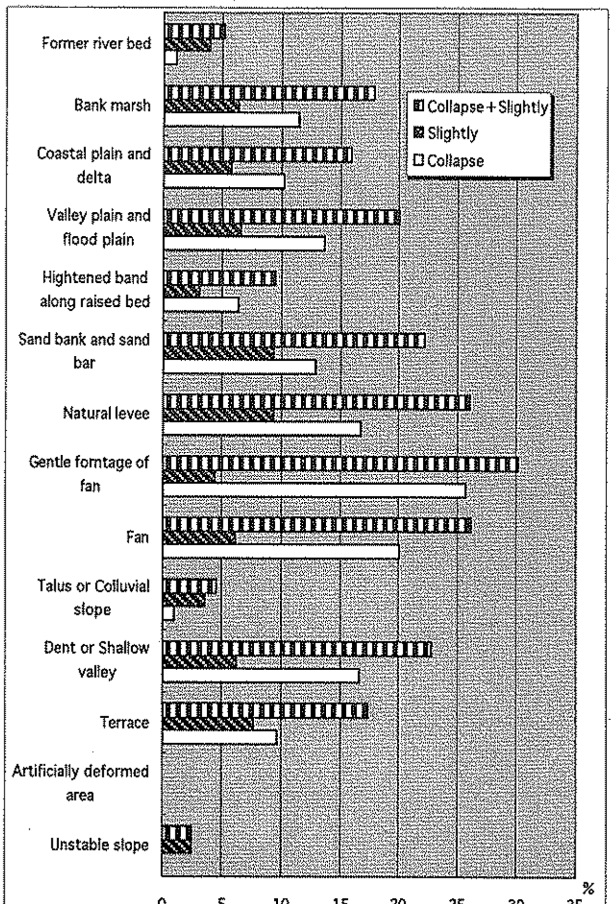
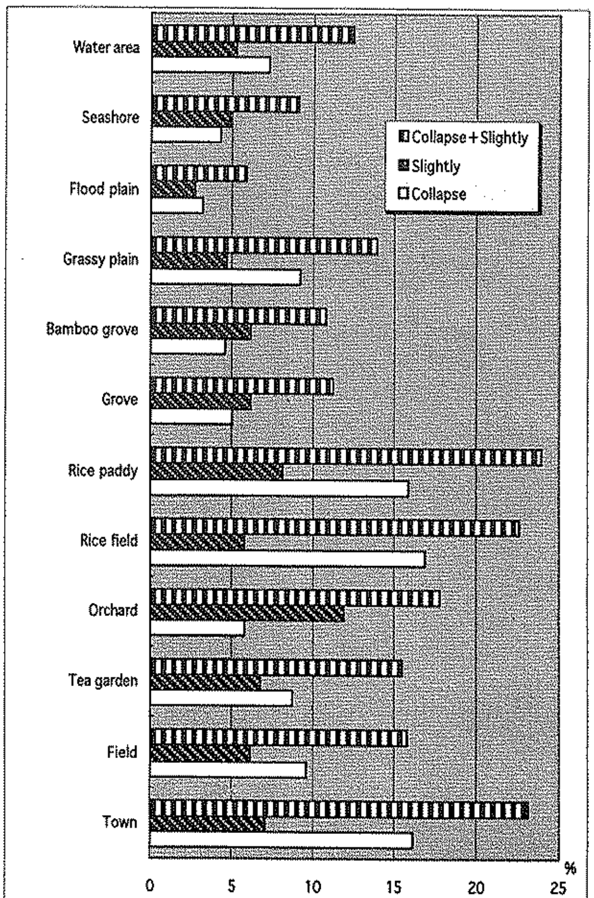


Fig-3 Area of Damage to Buildings in Each Land Condition



Area of Damage to Buildingsin Former Land Use

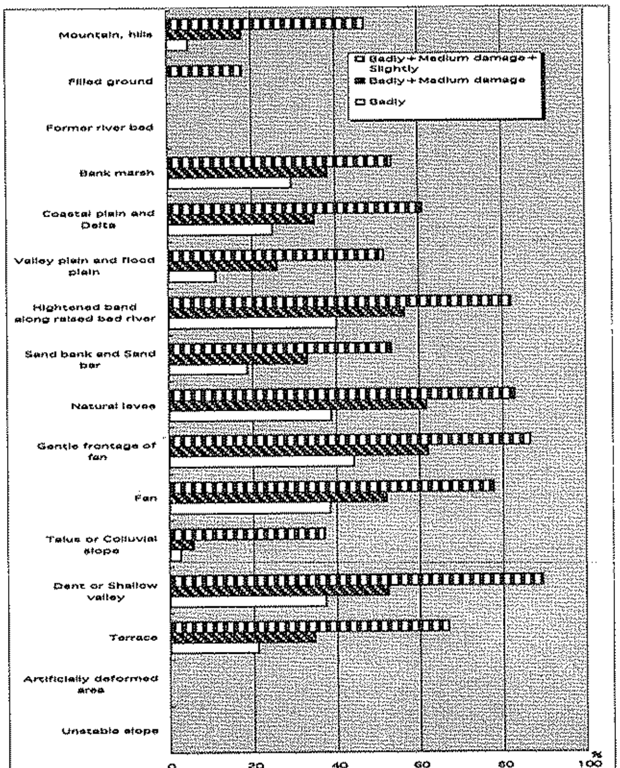
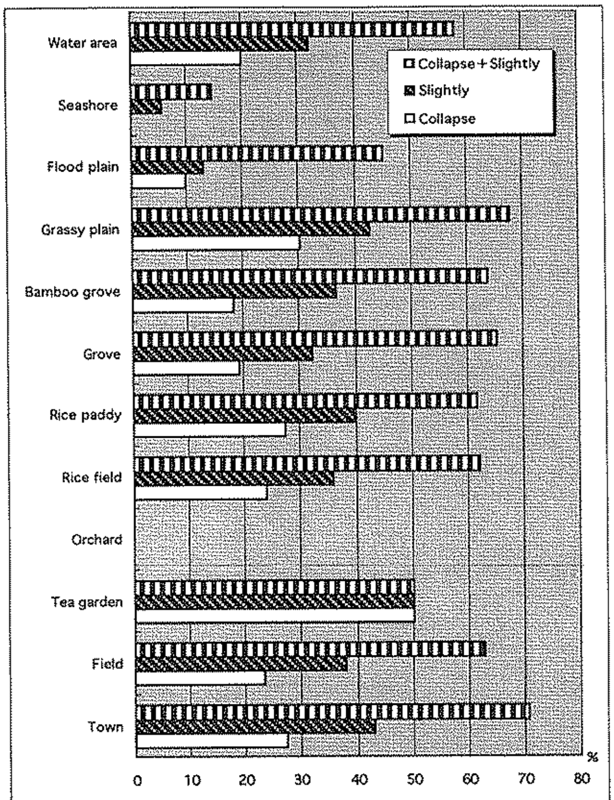


Fig-4 Ratio of Buildings by Land Condition and Damage Level



Ratio of Buildings by Land Condition and Damage Level

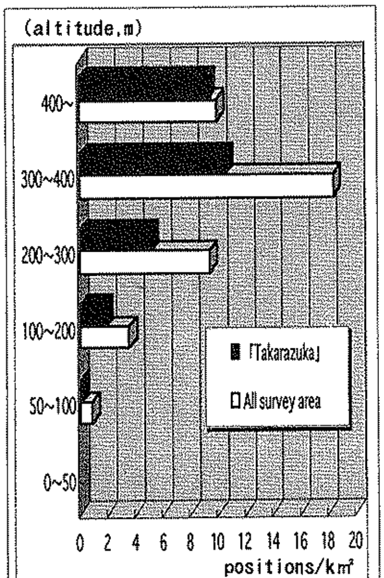
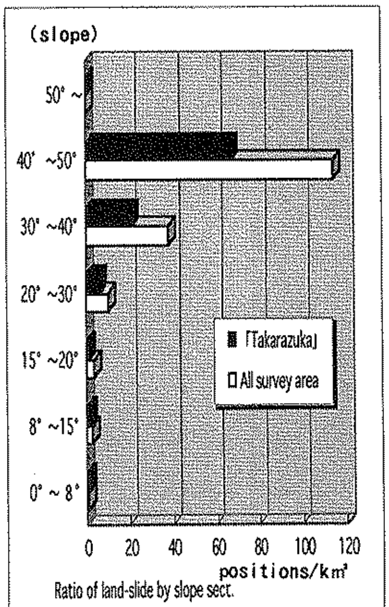
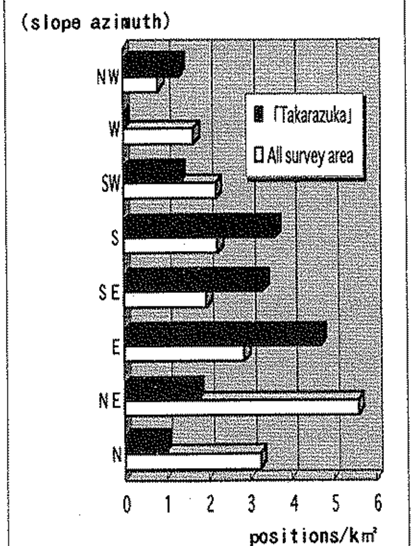


Fig-5 Ratio of land-slide by altitude sect.



Ratio of land-slide by slope sect.



Ratio of land-slide by slope azimuth sect,

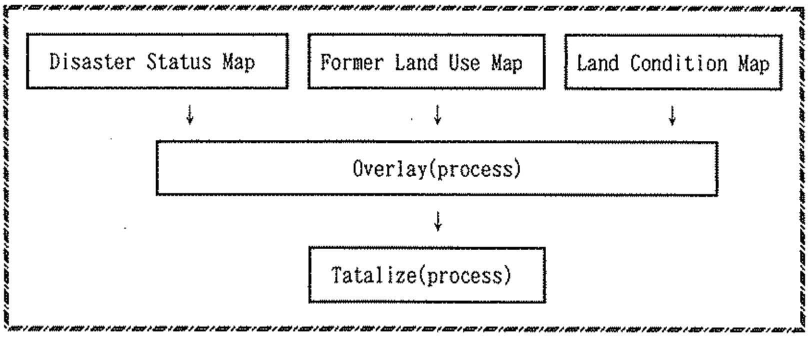


Fig-6 Liquefaction disaster analyzing flowchart

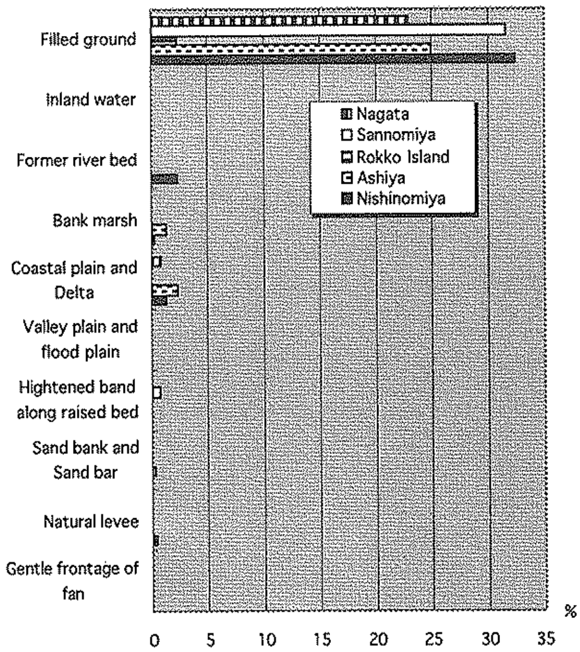
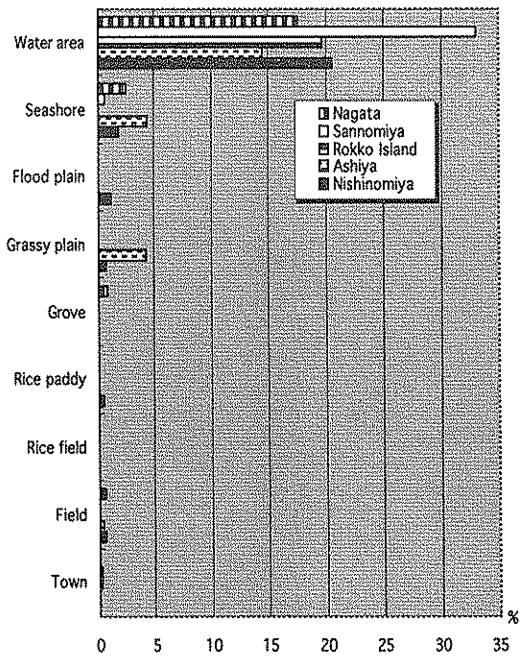


Fig-7 Ratio of liquefaction area in each land condition



Ratio of liquefaction area in each former land use