DEVELOPMENT OF EARTHQUAKE RISK ASSESSNENT SYSTEM USING GIS FOR SNOW COUNTRY

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SUMMARY:

Snowy district should pay extra attention to the complex disaster of snow and earthquake. We are holding many problems due to enlarged seismic disaster by collapse of piled snow on streets and roofs, moreover, securing escape route and space for the fire control and the rescue activities are the big difficulties. However, current disaster prevention measures are mostly considered for the time of the summer. In this study, the earthquake risk assessment system in consideration of the influence of snow is developed. As a result, applying the earthquake risk assessment system on Iijima, Tsuchizaki and Izumi district in Akita city in this study proved that there are major difficulties from the point of view of disaster prevention. It showed that there are regions that will be isolated and is forced to take detour for the rescue activity because the street blockage rate is increased in the snow season.

Keywords: earthquake in the snow season, earthquake risk assessment, GIS

1. INSTRUCTION

Snowy district as Hokkaido and Tohoku area need to promote disaster prevention measures which match to the regional necessities since piled snow on the streets and roofs possibly spread the damage and interfere rescue activities when earthquake occurs in the winter. For example, according to the 2004 Niigata-Chuetsu earthquake, the damage reflected the condition of nature and society which is different from the metropolitan area. However, current disaster prevention plans are mostly considered for the time of the summer, and there are few studies of seismic disaster assessment for snow season. Author took a careful watch about the earthquake disaster prevention in the snow season and extracted the fact that regional disaster prevention plans tend to be mineralized and uniformed, and also they have been verified that piled snow blocks streets and causes the access trouble. In this study, by constructing GIS database of ground, house age and road width, seismic risk assessment system that can shows the influence of snow is developed and examples of its application in Akita city is reported.

2. CONSTRUCTION OF DATABASE RELATING TO EARTHQUAKE RISK ASSESSMENT

2.1. Ground data

Ground database is constructed since constituent of ground formation affects extent of house damage. However there are methods of evaluating ground condition by using boring information and microtremor record, it is difficult to apply it to evaluate the whole city. Therefore, in this study, we constructed the ground database with ground characteristic by dividing thickness of alluvium into 3 models as 0m~10m, 10m~20m, 20m~30m.

2.2. Data of house age and road width

The database of house and road width is constructed based on the city planning map (1/2,500). Aerial pictures which are seen in photograph 1 were used to construct the database of houses by configuring their ages as; before 1970, 1971-1980 and after 1981, to follow the amendment of quake-resistance standards. House ages are classified as follow; "before 1970" for houses existed in the photograph of 1967, "1971-1980" for houses newly added in the photograph of 1979, and "after 1981" for the houses newly added on the city planning map. Road widths are classified in 4 levels for the database as; "under 4m", "4-6m", "6-8m" and "over 8m". Figure 1 is the distribution of houses and roads witch are classified by age and width according to the aerial photographs and city planning map.



Photograph 1. Example aerial picture used to classify houses by age (Near Iijima district, Akita city Left:1967 Right:1979)



Figure 1. Example of database of house age and road width

3. SEISMIC RISK ASSESSMENT METHOD FOR SNOW DISTRICT BY USING GIS

3.1. Procedure of seismic risk assessment

Figure 2 is the flow chart of the seismic risk assessment considering piled snow. Three risk factors, which are "house collapse", "street blockage" and "residential isolation", are the configuration of the risk assessment here. First, database is constructed by ground condition, house age and road width for the evaluation. Second, based on the damage function of age group of houses, the houses which may collapse when earthquake occurs are detected by ingenerating random number with Monte Carlo method. Then, street blockage is evaluated by using the street blockage prediction model constructed by the database of the house collapse situation and road width. Also, for the earthquake in snow season, damage rate of house collapse is increased because of the roof snow and road width is decreased because of the piled snow for the evaluation. Moreover, it can indicate streets and houses that will be unreachable by the vehicle from the main street by expanding snowplow support system and analyzing road network. This system has used DiMSIS, the GIS which are developed by Disaster Prevention Research Institute Kyoto University.



Figure 2. Flow chart of seismic disaster assessment considering snow

3.2. Street blockage prediction model

Structure of house, floor number, road width and intensity of seismic motion are highly concerned to induce street blockage. We assumed that the collapse of house causes the street blockage since 91% of street blockage was induced by house wreck in Kobe earthquake of 1995. Also, this prediction model detects totally blocked streets which allow no vehicle. The hypotheses are shown below.

- Based on the damage function of low-rise and stand-alone houses, houses which may collapse when earthquake occurs are detected by ingenerating random number using Monte Carlo method. And increase collapse percentage because roof snow affects house as load and house damage can be enlarged. (Data can be appropriately settable)
- 2) Wreckage width by house collapse is set as 3m. (Figure 3)

- 3) At the road width under 4m, it's considered as "blocked" if a single house along the street collapses. At the road width of between 4m and 6m, it's considered as "blocked" if both houses which stand opposite to each other collapse. The road width of over 8m isn't blocked. (Figure 4)
- 4) In snow season, it considers snow to pile 1m at the both side of the street. Therefore, road width decreases 2m from the original width. (Photograph 2)



Figure 3. Decrease of valid road width by the house wreck



Figure 4. Example street blockage by house collapse



Photograph 2. Picture of piled snow narrowed the street

3.3. Road network analysis function

Each node and link has identification number in addition to its coordinate and information of road width. This will help road network analysis to identify the shortest exit rote and unreachable street due to street blockage on GIS. Moreover, the positional relation between streets and house can be analyzed by setting identification number and age data on each of houses. As a result, houses which are isolated by the street blockage can be identified.

3.4. Support function to plan snowplow and renovation for earthquake-resistant structures

As a part of disaster prevention measure, snowplow and renovation for earthquake-resistant are necessary to be proceeded gradually by planning well with the decision of priority, however they may cost much time and money. Information of houses and streets are automatically displayed by inputting ID, the function is extended to be able to reflect situation of snowplow and renovation. Piled snow (2m) is considered to be removed completely. For the houses which have renovated are considered not to be collapsed.

Figure 5 shows the seismic risk assessment system that we developed in this study. This system can indicate disaster risk according to ground information, road width, and house age. The simulation can be held with the selections of earthquake that occurs when it snows and it doesn't snow, and also number of simulation and rate of house collapse can be set as necessary (see upper left in the figure). The map shows simulation results under those conditions (see right in the figure), and street blockage rate is calculated and indicated automatically (see left-center in the figure). Moreover, streets and houses which may be unreachable due to street blockage can be detected and indicated by using road network analysis. Setting of the streets to be snowplowed and the houses to be renovated can be configured as necessary.



Figure 5. Seismic risk assessment system (Example display of snowplowed streets)

4. EXAMPLE APPLICATION OF SEISMIC RISK ASSESSMENT SYSTEM ON AKITA CITY

The simulation on the seismic risk assessment system which was developed in this study was applied on Iijima, Tsuchizaki and Izumi district in Akita city to investigate the influence of snow against street blockage and house isolation at the time of earthquake in snowy district.

4.1. Conditions of target districts

Figure 6 shows the ground condition of target districts. Figure 7 shows the distribution of house age and street width. See below for distribution of street width and ground characteristics of each district. Iijima district is located in northern of Akita city, many houses which were built before 1971 make residential area random with farm road. Road condition is bad and most of the streets are narrow as less than 4m in general. As the ground condition, there is 10m to 20m of alluvial in the south and 0m to 10m of alluvial in the north.

Tsuchizaki district is an old seaport, there are many houses which were built before 1970 and streets which are less than 4m in width. As the ground condition, it's mostly 10m to 30m of alluvial.

Izumi district is located in the center of Akita city, there are a lot of houses which were built before 1970 along the main road which is running north-south. There are also many newly built houses around the area and most streets are wide as more than 6m in width. As the ground condition, it's mostly 10m to 20m of alluvial.



□Thickness of alluvial 0m~10m

Figure 6. Ground condition



Figure 7. Distribution of house age and road width

4.2. Assessment of street blockage and house isolation

Considering inland earthquake in Akita city, strength of earthquake motion is varied according to the thickness of alluvial. It assumes to be intensity 6 lower in the area of 0m to 10m alluvial. (rate of house collapse: 5% for houses built before 1970, 1% for houses built between 1971 and 1980, 0% for houses built after 1981) It assumes to be intensity 6 upper in the area of 10m to 20 alluvial. (rate of house collapse: 22% for houses built before 1970, 13% for houses built between 1971 and 1980, 3% for houses built after 1981) It assumes to be intensity 7 in the area of 20m to 30 alluvial. (rate of house collapse: 47% for houses built before 1970, 28% for houses built between 1971 and 1980, 8% for houses built after 1981) Assumption of house collapse rate is increased to 40% because of the roof snow. Regarding to 100 times repetition of the simulation, the rate of street blockage is defined as A/C x 100, and the rate of inaccessibility is defined as $B/C \ge 100$ by the definition of A as the time that streets are blocked, B as the time that houses are isolated, and C as the time that simulation is repeated. Figure 8 is the distribution of street blockage rate in Tsuchizaki and Izumi district at the time of earthquake in other than snow season in the snow season. This tells that blockage rate of most streets in Iijima district becomes less than 30%, however, street blockage rate becomes 30% to 80% partly for the streets which width are less than 4m at the time of earthquake in the snow season. On the other hand there are many streets which blockage rate becomes more than 30% when earthquake occurs in snow season, there are also the streets with blockage rate of 80%. Street blockage rate can be high at the time of snow season earthquake especially in the district like lijima where there are new houses and narrow streets. Because there are many houses which were built before 1970 and streets which width are less than 4m, Tsuchizaki district has many street blockage both in the time of earthquake in the other than snow season and in the snow season. Street blockage rate for most of the streets in Izumi district becomes less than 30%, however at the time of earthquake in the snow season, streets blockage rate increases rapidly to 80%.



under 30%



between 30%~80%

Street blockage rate over 80%

Figure 8. Distribution of street blockage rate when earthquake occurs in other than snow season (above) and in the snow season (below)



Figure 9. Distribution map of risk of house isolation: other that snow season (above) and in the snow season (below)

The street blockage rate of these three districts at the time of earthquake in other than snow season and in the snow season becomes as follow; (other than snow season 2%: snow season 9%) in Iijima, (ordinary season 10%: snow season 24%) in Tsuchizaki, and (other than snow season 3%: snow season 18%) in Izumi. In comparison with the average street blockage ratio, it becomes 5% in other than snow season and 17% in the snow season which means that the street blockage rate is increased 3.4 times larger by above hypothesis. Figure 9 shows the distribution of houses isolation risk at the time of earthquake in other than snow season and in the snow season. The fact that many districts hold problems from the point of view of disaster prevention is found in high risk of house isolation.

4.3. Risk of house isolation under circumstance of snowplow and renovation for earthquake resistance

For the example to consider the earthquake disaster prevention measure, we made risk assessment of house isolation by assuming snowplow and renovation for earthquake resistance have been applied. Figure 10 shows the example how risk rate of house isolation changes after snowplow and renovation. At the time of earthquake in the snow season, access streets toward residential area are blocked and so many areas including designated refuge shelter are found as the place with high isolation risk. However, snowplow and renovation can decrease isolated houses.



Figure 10. Example differences in risk assessment of house isolation by applying snowplow and renovation for earthquake-resistant structures

5. CONCLUSION

In this study, earthquake risk assessment system that can shows the influence of snow is developed. The fact that many districts hold problems from the point of view of disaster prevention since street blockage which causes the area to be detoured and isolated for the emergency activity after earthquake is increased especially in the snow season. Since there is diversity of earthquake risk assessment in snowy district, at the time of that damage reports of winter earthquake haven't been found enough, additional consideration of proper use of the data is necessary to be discussed in the future. However, new data from the future investigation makes assessment quality more accurate since rate of house collapse and width of house wreck can be input independently on each house and street to predict the risk. This system can prioritize the investigation of emergency route, snowplow and renovation for earthquake resistance by considering the further rescue activity and earthquake disaster prevention measure for snowy district.

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