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A Case Study for Development of comprehensive Seismic Risk Assessment

——Part 2 Prevention of the earthquake disasters on the basis of the seismic risk assessment——

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総合地震危険度評価法に関する研究

——（その２）総合危険度評価に基づく地震災害の低減——

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This study is each composed of the part 1 and 2. In the part 1 of this study was previously published in 1986. The authors were described the mechanism of damage occurrence and estimation method of earthquake damage in the study of part 1.

The prenent paper, part 2, described the preventive measures based on the damage estimation result in Nagoya city for the case study. Three types of earthquake damage are estimated in Nagoya city. One of them is the totally destroyed wooden houses caused by the strong ground motion, liquefaction and man-made ground area. Second one is the fire damage such as outbreak and its spreading fire damage. Last one is the human damage such as loss of life. The comprehensive seismic risk in Nagoya is assessed on the basis of addition to the various damages mentiond above.

1. INTRODUCTION

Large earthquakes have frequently occurred in Japanese Islands, especially in the Pacific Ocean region. Nagoya city, the fourth largest city in Japan located halfway between Tokyo metropolis and Osaka city along the central Pacific Ocean coast, has suffered from enormous damages from past earthquakes. Nagoya city covers an area of about 320 square kilometers, the greater part of the ground being a thick alluvium. At present this city has a population of more than two millions. Moreover, the present circumstances have become quite different from the past ones, even from those of thirty years ago. Surrounding country areas have been converted into urban areas and many houses have been built on undesirable places such as man-made slopes and riverbasins. Due to these developments, earthquake damage in Nagoya is concerned in near future.

The discussion of earthquake prevention has a very important significance in Nagoya city, from because locality of Nagoya has three important circumstances such as activity of earthquake around the city, construction of ground structure and locality between Tokyo and Osaka city. And also, the characteristics of earthquake prevention factors which will be carried out from this case study will be able to apply the other cities.

2. EARTHQUAKE CIRCUMSTANCE

At first, in order to discuss the future earthquakes which will bring about damages in Nagoya city, it will be serviceable to reviews the past large earthquakes. Only the epicenters and magnitudes of the earthquakes, of which Japanese Seismic Intensities in Nagoya are greater than V, are shown in Figure 1. Occurrence of earthquakes with magnitude greater than 8 (Ms scale) are distributed along the Pacific Coast, with the exception of the giantic earthquake with magnitude 8.4 (Nobi Earthquake) occurred in the inland area in 1891. The authors have tried to take those three earthquakes which are shown with black circles in Figure 1 as the case for the study of the damage estimation in Nagoya city, and their fault models are shown in the same figure with squares.

In the second place, the density of wooden house in each mesh area will be shown in Figure 2. The

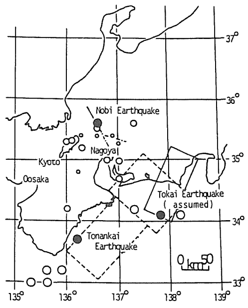

Figure 1 Distribution of the earthquake epicenter which bring about damages, and its fault models.

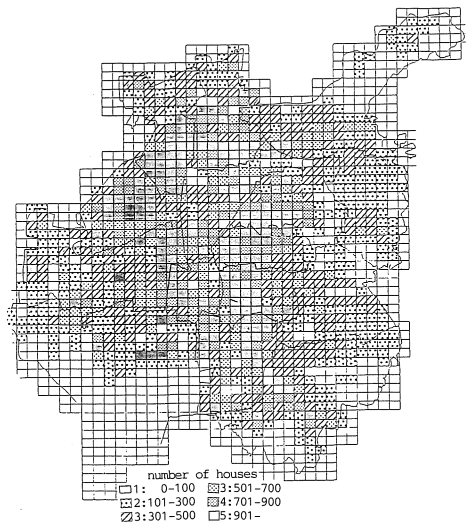

Figure 2 The distribution of the density of wooden house.

crowded areas more than 900 houses per mesh area are included in a circle with a radius of about 7 kilometers. The 70 percents of crowded areas are concentrated in the north-western and south-eastern part of the city.

Finally, the whole area has been classified into six classes, depending on the ground structure as listed in Table 1. As shown in Figure 3, the classification 3 and 4 distribute from northern to western part, and southern part in the city. In the eastern part, classification 1 and 6 are concentrated.

3. ESTIMATION OF EARTHQUAKE DAMAGE IN NAGOYA CITY

3. 1 Maximun response acceleration on the ground surface

Seismic response spectra on the seismic basement are calculated by the equation 1 (see part 1)[1] for

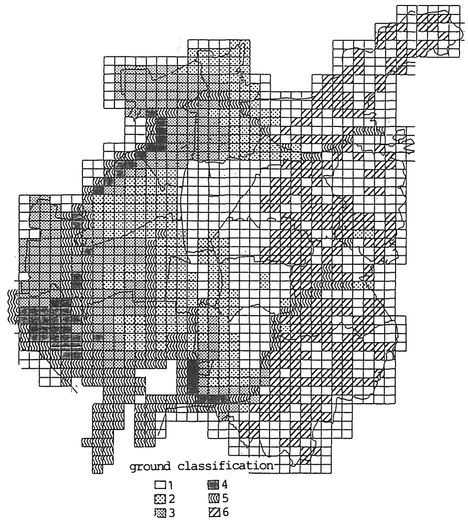

Figure 3 The utilization of land depending on the ground structure.

Table 1 Ground classification depending on the its structure.

classification	Ground structure
1	Tertiary and Diluvium
2	Alluvium (less than 10 meters)
3	Alluvium (10 to 20 meters)
4	Alluvium (more than 20 meters)
5	Riverbasin,seaside and canal
6	Man-made ground

Table 2 The calculated results of maximum acceleration in the seismic basement for the assumed earthquakes.

Assumed Earthquake	Referrence Earthquake Name	Magnitude	Distance from epicenter(km)	Calculated result Maximum Acc.(gal)
1	Ansei	8.0-8.4	170	70
2	Tonankai	8.0	100	100
3	Nobi	8.4	50	120

assumed earthquakes shown in Figure 1. The results of maximum acceleration values which are calculated at nine localities; four corners, one center and four middle points of side line in Nagoya city and those are listed in Table 2. The calculated results of the assumed earthquakes in Table 2 are about 70, 100 and 120 gals[2] as an average data from nine localities on the Tertiary mentioned above sites, respectively. Authors use these values with calculation of damage estimation as following chapters. The various damages will be estimated to three assumed earthquakes, however, their damages will be only shown in a case of the assumed earthquake 2 in following sections.

In case of assumption which the ground structure in Nagoya consists of flat layers, the maximum acceleration on the ground surface is calculated by the multiplication of the maximum acceleration on the

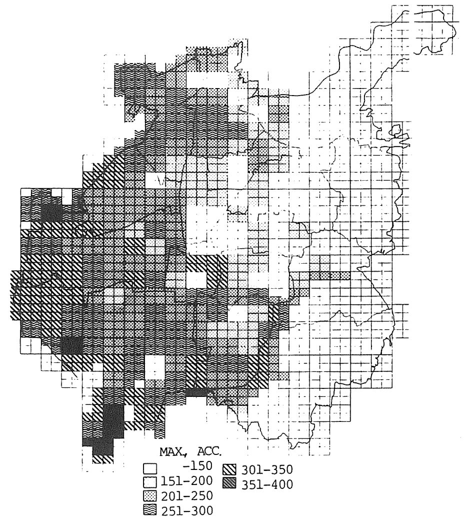

Figure 4 The calculated result of maximum response acceleration on the ground surface for the assumed earthquake 2. In a case of assumption which the ground structure is consisted with flat layers.

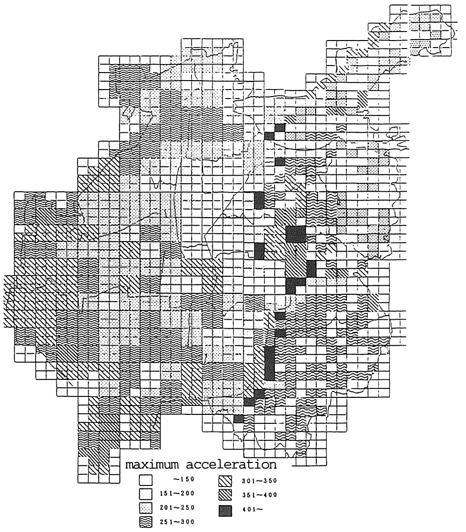

Figure 5 The calculated result of maximum response acceleration on the ground surface for the assumed earthquake 2. In a case of considering the ground irregularity.

seismic basement (see Table 2) and the the amplification factor in each mesh area for the assumed earthquake 2, and their results are shown in Figure 4.

The calculated maximum acceleration increases from the eastern to the western part of the city. The maximum acceleration in the western part is more than 300 gals, but in the eastern part is less than 150 gals. Megascopically saying, this tendency is corresponding to change the thickness of the alluvium layer shown in Figure 3. And also this tendency agreed with the conclusion that is the eastern part-part of the city to be relatively safer than the western side of the city concerning on the earthquake occurrence.

In seismic response analysis of the man-made ground, the following investigations are done in Nagoya city.

(1) Distribution of slopes

(2) Detailed field survey of the man-made ground, including shape, geology and its form

Distribution of slopes is due to an aerial photographs. The field survey is not necessary to collect data shape and others, but also to judge whether the slopes found in photograph are man-made ground or not. The amplification factor of man-made ground is calculated on the bases of the above ground shapes. In the assumed earthquake 2, the calculated result of the maximum acceleration is obtained by means of the multiplication of amplification factor in flat area and amplitude of man-made ground in each mesh area, and is shown in Figure 5.

By comparison the calculated maximum acceleration on the ground surface in Figure 4 and 5 to the utilization of land in Figure 3, it is considered that the characteristics of seismic ground motion in a regional scale. By comparison the maximum acceleration shown in Figure 4 to the utilization of land in Figure 2, when before the turning into housing lots, the geological condition from eastern to western part in Nagoya starts from Tertiary to Diluvium through thick Alluvium. However, at present, we can find that there are many artificial flatted ground such as man-made one at the eastern hill-side of the city. By comparison such former ground structure with estimated maximum acceleration shown in Figure 3, the maximum acceleration increases from the eastern part to the western part of the city and it was harmonized with the change of ground structure as described earlier. This tendency agreed with the conclusion that is the eastern part of the city to be relatively safer than the western side of the city concerning on the earthquake occurrence. However, it did not reveal the calculated acceleration depending on the present reconstructed ground structure and it differed from the results shown in Figure 4. In another word, the area with large acceleration appears at the eastern part of the city, and the damage will be estimated at the eastern housing lots area.

It could not make the accurate seismic assessment with the response analysis which belongs to the S-wave Multiple Reflection Theory. Therefore, it is

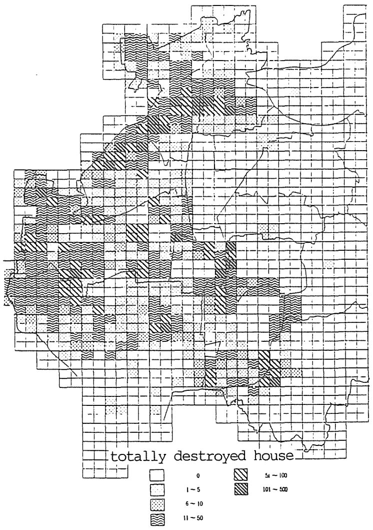

Figure 6 The estimation result of wooden houses caused by strong ground motion and by liquefaction.

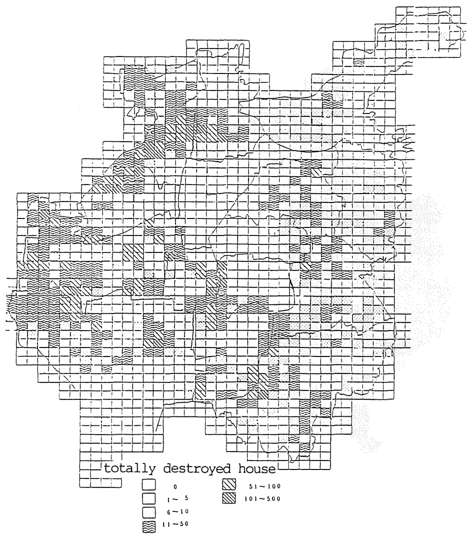

Figure 8 The estimated result of totally destroyed house due to earthquake 2.

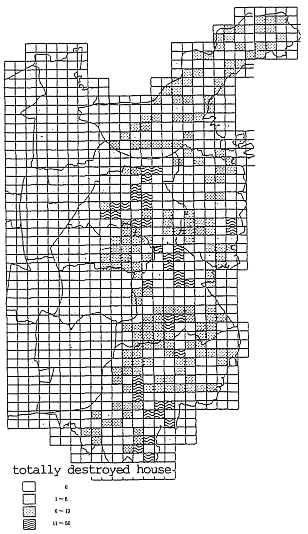

Figure 7 The estimation result of wooden house caused by man-made ground destruction.

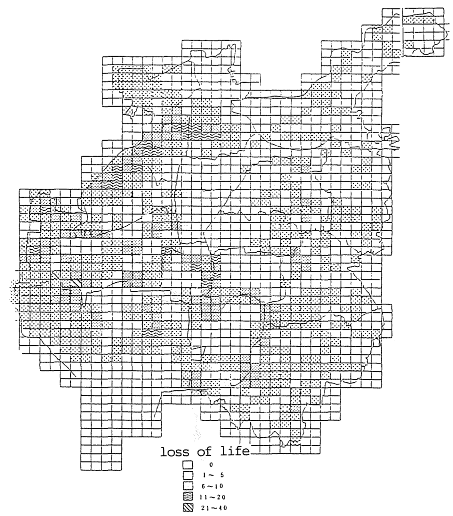

Figure 9 The estimated result of loss of life.

necessary to make the seismic assessment with the consideration of the topography and artificial ground structure such as man-made lands.

3. 2 Estimation of wooden houses damage

Concerning the totally destroyed ratio evaluated from equation 16[1)] (see part 1), the number of totally destroyed houses has been calculated by multiplying the number of wooden houses with $P_1(a)$ and $P_2(l)$, and with $P_3(m)$ in each mesh area. The damage distributions calculated from $P_1(a)$ and $P_2(l)$, and from $P_3(m)$ are shown in Figure 6 and in Figure 7. By comparison the estimated number of totally destroyed houses caused by the maximum acceleration to the utilization of land, the number of totally destroyed house is considerably great at the area of the ground classification 3 and 4. In another word, the damage increased with increasing the thickness of Alluvium. Although the number of totally destroyed houses is very small amount and becomes less than 10 at the area of ground classification 3 and 4 at southern part of the city, this does not mean the less damage ratio at those areas. That is clear with the reference of

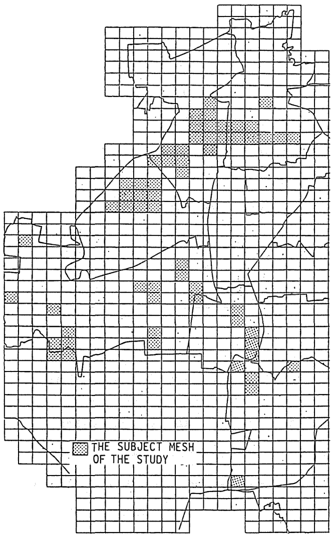

Figure 10 The area which are estimated the fire damage caused by spreading.

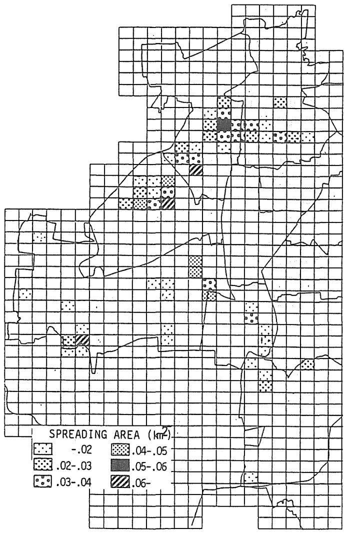

Figure 11 The estimated result of spreading fire damage.

Figure 2 and the less amount of wooden houses existing in those mesh areas. By comparison the distribution of the number of totally destroyed houses at man-made ground sites as shown in Figure 7 with Figure 6, at the eastern part of the city. it has been believed that there seemed relatively small earthquake damage because of hill side areas, but, it can not say definitely safe as considering with the present situation of the development of social circumstances at the eastern part of Nagoya city.

By using the synthesized various earthquake damages which are caused by maximum acceleration, liquefaction and destructive man-made ground, the whole damage of totally destroyed houses is revealed in Figure 8. The relatively minor damage for wooden houses is observed at the areas of both ground classification 1 and 2 which are at the center and the eastern part of the city. The moderate damage is observed at the areas belong to both ground classification 3 and 6. On the other hand, the major damage is observed at the ground classification of 4 and 5. In addition, the same degree of damage is found at the ground classification 3 and 6. This means that the degree of earthquake environment at the ground classification 6 as that of the classification 3 (thickness of Alluvium is from 11 to 20 meters) is obtained the land development even with the originally hard ground structure.

3. 3 Damage estimation results of loss of life

In Figure 9, the estimated results of number of loss of life in each mesh area is shown. The areas where the number of loss of life is estimated more than 11 are mainly concentrated in the north-western part of Nagoya city.

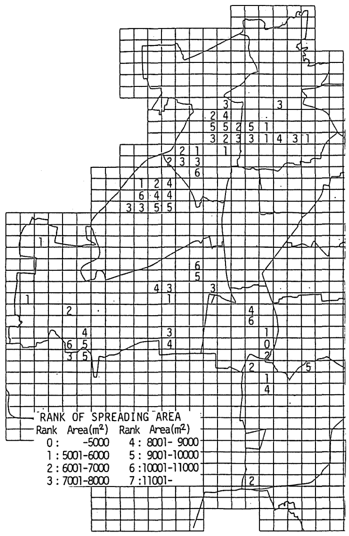

Figure 12 The risk of fire damage bases of the spreading fire area.

3. 4 Damage estimation of outbreak fire and spreading area

In Figure 10, the estimated result of the number of outbreak fire in each mesh is shown on the bases of equation 27, 28 and 29[1)] (see part 1). In addition, the damage estimation result of fire spreading is evaluated in the mesh which is shown in Figure 10 based on both the damage of outbreak fire and the influence of the residential enviroment consisting of the house crowed ratio, the vacant land, the stream, and so on. The area using damage estimation is 15.25 km^2.

Table 3 Classification of the damage rank.

Various damage		Classification of damage and degree of rank							
Maximum acceleration	(gal)	-150	151-200	201-250	251-300	301-350	351-400	401-450	451-
Rank		0	2	4	6	8	10	12	14
Totally destroyed wooden house		0	1-5	6-10	11-50	51-100	101-500	501-700	701-
Rank		0	1	2	3	4	5	6	7
Number of loss of life		0	1-5	6-10	11-20	21-35	36-50	51-80	81-
Rank		0	1	2	3	4	5	6	7
Damaged area of spreading fire	($\times 10^3 m^2$)	-5	5-6	6-7	7-8	8-9	9-10	10-11	11-
Rank		0	2	4	6	8	10	12	14

Table 4 Earthquake risk assessment according to the total value of damage rank.

Earthquake Risk	Range of total rank value	Seismic Intensity and general remarks of various damages
0	0	Seismic Intensity is less than IV. Damage is extremely low.
1	1 - 5	Seismic Intensity is about V. Damage of wooden house is only presumed.
2	6 - 10	Seismic Intensity is less than middle VI. Occurrence of damage to wooden house and loss of life is presumed.
3	11 - 15	Seismic Intensity is middle VI. Possibility of damage occurrence to wooden house, loss of life and outbreak fire is relatively hight.
4	16 - 20	Seismic Intensity is more than middle VI. Possibility of all damage occurrence is extremely hight, but, damage of spreading fire is small.
5	21 - 36	Seismic Intensity is VII. Possibility of all damage occurrence is extremely hight, especially, damage of spreading fire is great.

The estimated results on spreading fire after 60 minutes from outbreak fire is shown in Figure 11. On the north western part of Nagoya city, there are many areas where the spreading fire area per one mesh reveals greater than 0.03 km^2. It can be seen that the spreading fire area is approximately 7 per cents and 13 per cents of the damage estimation area under the wind velocity of 3.7 m/sec and 10.0 m/sec, respectively. Here, authors estimated the spreading area mentioned above, has been estimated regarding many number of outbreak fires. Therefore, it has been converted into the spreading area per mesh and per outbreak point. The risk of spreading fire shown in Figure 11 under the condition of the wind velocity of 3.7 m/sec and 60 minutes after outbreak evaluated. The risk of spreading fire is classified into 8 grades and each value is given in Figure 12. There are 15 meshes for the rank of risk having more than 5 and it becomes approximately 25 percents of the whole meshes in the city. Regarding the area having the rank of more than 5, the half of those areas is concentrated in the north-western part of Nagoya city and the risk of fire caused by earthquake is relatively high with respect to the other parts.

3. 5 Earthquake risk assessment by synthesizing various damage

The calculated response maximum acceleration at the ground and the estimated various damages are classified into the rank from 0 to 14 which is corresponding to their degree (see equation 34 in part 1)[1], and is given in Table 3. Here, the rank of maximum acceleration and of spreading fire are greater than the others. This reason is that the all earthquake damages are mainly governed by the maximum acceleration at the ground, and the spreading fire damage is seriously affected with people's property and life, moreover, spreading fire has a strong possibility in the development of the damaged area as known from the past earthquakes such as The Kanto Earthquake in 1923.

The earthquake risk is numerically obtained by using the total rank value which is given by the summation of various damage rank. The assessment on the bases of this earthquake risk is consisting of six degrees depending on the range of total rank value as shown in Table 4. The minimum earthquake risk 0 which total rank value means zero is the most safe assessment which seismic intensity is less than IV and the possibility of damage occurrence in this risk area may be extremely low. The maximum risk 5 which total rank value is more than 21 shows the most danger assessment which seismic intensity is VI. This rank 5, also, including the high possibility of all earthquake damages with special referrence of spreading fire.

The distribution of earthquake risk value in each mesh area is shown in Figure 13. As will be seen in this figure, the western and north-western parts in Nagoya are evaluated as dangerous area where the earthquake risk is greater than 3. Especially, in the

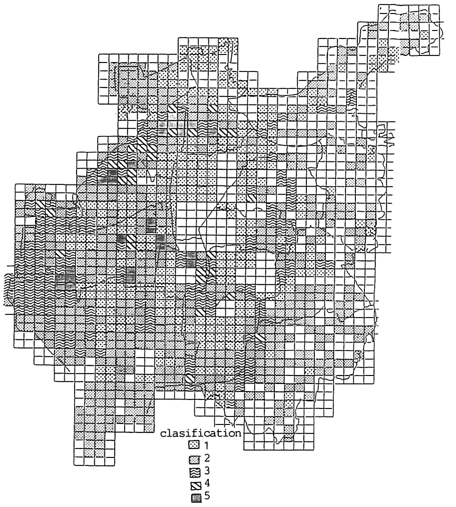

Figure 13 Evaluated the earthquake risk value in each mesh area.

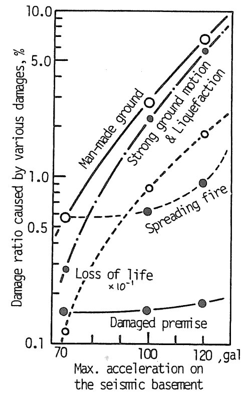

Figure 14 Estimated result of various damages for 3 assumed earthquakes.

north-western site among areas mentioned above, its risk is given as the highest value of 5 and this site will be considered that the disaster potential is the greatest in the city.

On the other hand, the earthquake risk value in the eastern part of the city is less than degree of 2. By comparison with this risk and ground utilization (in Figure 3), it is clear that the reagion the risk 2 in the eastern side of the city mainly dues in thedeveloping area where is truning the natural land into man-made housing lots. Therefore, the city planning in future should be required to prevent from the earthquake disaster in concerning with the man-made ground in mentioned above area.

The lower value of earthquake risk 0 or 1 appears at the center and eastern part excepting the man-made ground area in the city. The ground structure of those areas is consisting of hard soil layers, and there are few wooden houses with respect to other parts.

On the basis of this earthquake risk assessment, the western and north-western part may be evaluated the most dangerous areas in Nagoya. In the eastern part, there is high risk due to man-made ground, but, other area except man-made ground is relatively minor risk. The central part of the city is assessed the most safe area in Nagoya city.

4. DISCUSSION

Although the degree of earthquake risk is estimated as shown in Figure 13 in a case of an earthquake with the acceleration, 100 gals, of incident wave in the seismic basement, it is necessary to consider reduction of the earthquake risk for future earthquake prevention project. Hence we are try to elucidate the reduction factors respect to the earthquake damage and total risk by ground condition, maximum acceleration and soil circumstances. After we analyze the estimated various damages in detail and obtain the reduction factors, we should discuss the possibility of earthquake risk.

As the earthquake damage is clearly depended on the acceleration on the ground, relation between each earthquake damage and maximum acceleration of the incident wave are plotted in Figure 14, in which the maximum accelerations are of assumed earthquakes in Table 2 and damage ratios are the average one in all the meshed areas.

Damage of wooden houses by seismic vibration and liquefaction, damage of wooden houses on man-made ground and loss of life increase exponentially against the maximum acceleration and their patterns are quite similar each other. However, the burnt ratio and fire spreading ratio are almost constant at the acceleration of 70 to 100 gals and increase at 120 gals. This tendency is depending on a number of outbreak fire. Namely, the burnt and fire spreading ratios are controlled by the destroyed ratio of wooden house. They increase rapidly when the totally destroyed ratio exceeds a certain value.

When we pay attention on the occurrence types of damage by the incident wave, we can find that it is necessary at first to reduce the damage by outbreak and spreading fires for the regional earthquake prevention. In other words, we should consider to reduce the destroyed ratio of wooden houses and to promote construction of fire-proof houses and open space. Here we analyzed various damage in detail taking into consideration of the destroyed and mixed ratio of wooden houses in each meshed area.

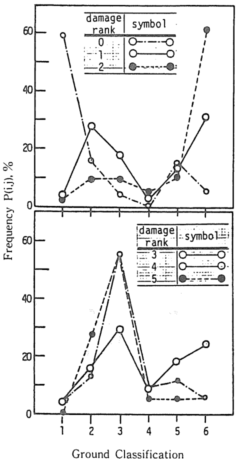

Figure 15 Relation ship between classified ground and prequency of damage occurrence in each rank of damage.

4. 1 Totally destroyed ratio of wooden house

Investigating which factor affect the damage of wooden house, we draw Figure 15 where the relation ship between classified ground and frequency of damage occurrence in each rank of damage defined in Table 2. The frequency, p(i, j), is defined as follows;

$$p(i, j)=n(i, j)/N(i)\times 100 \quad \cdots\cdots(4.1)$$

where N(i) is total number of mesh areas with damage rank i (Table 3) and n(i, j) is number of the areas with damage rank i and classified ground j. Although the grounds with high p(i, j) value are different from each case of damage rank, the large value of p(i, j) are seen in the cases of ground (3), (5) and (6). Particularly in ground (3), p(i, j) at damage rank (3), (4) and (5) are high, whereas, damage rank (1) and (2) occur frequently in ground (6).

Figure 15 shows that damage ratio is rare in the ground (1) and about 46 % of the ground (4) is suffered from damage rank 3. Roughly speaking, damage ratio is high in the ground (3) and (4). Damage rank 1 and 2 showing low damage occur frequently in the ground (2) and (6). Frequency of damage rank (3) is also high in the ground (6).

Based on the occurrence of damage of wooden house, we consider the prevention for future earthquake damage. When we try to constrain total damage ratio within 20 %, it is necessary to prevent the earthquake damage for the ground (3) to (6). As the ground (3) and (4) are composed of thick Alluvium layer and reforms of the ground are realistically improbable as prevention project, we should concentrate to improve earthquake-proof of wooden house. In the ground (5), damage rank 3 is caused by liquefaction and damage rank 1 is due to scarcity of wooden house in meshed area. Prevention project for liquefaction is inevitable at the former case, and at the latter case, we should keep the man-made circumstance of wooden house population or construct house after improvement of the ground for liquefaction.

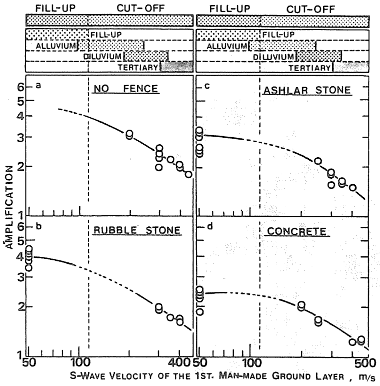

Figure 16 Relation between Vs of man-made ground and amplification in each case of protection fence of slope.

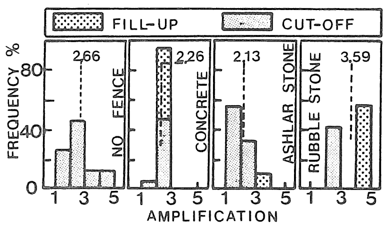

Figure 17 Frequency of amplification in each type of fence.

Prevention guide in the ground (6), i. e, man-made ground, is deduced from the following.

(a) Figure 16 show relation between S-wave velocity (m/s) of man-made ground and amplification in each case of protection fence of slope. It is clear that amplification decreases with increase of S-wave velocity in every ground and decrease by the fence. Compareing with amplification in no-fence ground to concrete fence ground, the latter is about 60 % of the former one. The amplification decrease is large particularly in fill-up ground.

(b) Figure 17 shows frequency of amplification in each type of fence. Very high amplification, more than 3, is observed in no-fence cut-off ground and ashlar and cobble stone fence fill-up grounds.

On the other hand, amplification is less than 3 in all the concrete fence ground. Hence it can be concluded that concrete fence in both the fill-up and cut-off grounds will be effective reduction of the amplifi-

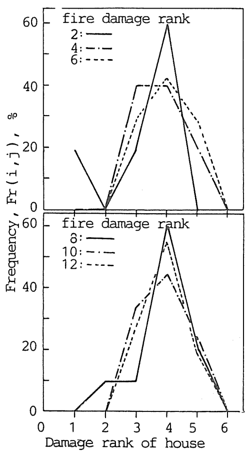

Figure 18 Relation between the rank of totally destroyed and rank of fire damage.

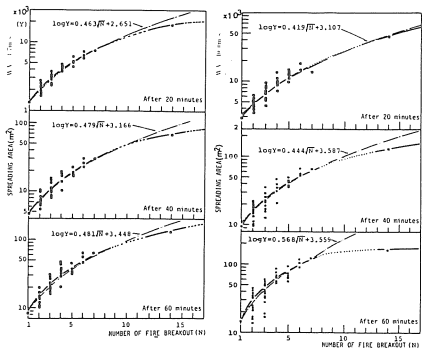

Figure 19 Relation between the outbreak fire number and spreading fire area.

cation. As a realistic earthquake prevention, it will be necessary to use the concrete fence at least in fill-up ground.

4. 2 Damage of outbreak fire and spreading

Although the damage by outbreak fire and their spreading relate indirectly to the amplitude of ground motion, the direct causes of outbreak fire are considered as the breakdown of wooden houses and the dangerous fire materials such as room heater, boilers and chemicals and that of spreading fire relate to the crowded ratio of wooden houses, wind velocity and so on.

The first of all, the relation of the frequency of fire damage, Fri, j, between the rank of totally destroyed and rank of fire damage, which is of the damage by outbreak fire and their spreading, was shown in Figure 18. Here, Fr(i, j) was defined by equation.

$$Fr(i, j)= \sum_{i=1}^{8} N(i, j)\cdot Rf(i)/ \sum_{i=1}^{8}\sum_{j=1}^{6} N(i, j)\cdot Rf(i)\times 100 \cdots\cdots\cdots (4.2)$$

Where Rf(i) is the rank value at fire rank, i, reffered from Table 3, and N(i, j) is the number of mesh at fire rank (i) and at the damage rank (j) of wooden houses. As can be seen in Figure 18, there was the predominant peak at the damage rank 4 of wooden houses at any fire ranks. Therefore, it can be concluded that the probability of fire damage is relatively high at the area with the damage rank 4 of wooden houses. As compared Figure 18 with Figure 15, in Figure 15 the damage rank 3 of wooden houses revealed themaximum frequency value concerning on the fire damage, there was the anomalously large frequency at the damage rank 4 of wooden houses among any other damages. As a result of this, at the view of the prevention of spreading fire damage of wooden houses caused by earthquake, it will be concluded that the measures for the earthquake damage control at the area of rank 4 in Figure 18 is extremely important rather than the measures for disaster control at the area of damage rank 3 that revealed the maximum frequency value of the damage of wooden house in Figure 15.

In Figure 19, the relation between the outbreak fire number and spreading fire area is shown at two different constant wind velocity that is 3.7 and 10 m/sec. It is concluded that the spreading fire area is proportional to the outbreak fire number and increased with the increased of wind velocity. The tendency of those relation is similar to that of damage of wooden houses and increased exponentially. The general formula of those is given by equation

$$\mathrm{Log}\ Y = c\cdot \sqrt{N} + k \cdots\cdots\cdots (4.3)$$

Where Y and N show the spreading fire area and the number of outbreak fire, respectively. It is suggested that the outbreak fire number give the strong effect to the damage of spreading fire.

On the other hand, concerning on the effect of wind velocity to the spreading fire area, the increase ratio of spreading fire area has the same percentage as that of wind velocity. This shows the same results from equation (4.3). For example, as Y2i is the spreading fire area after i minutes from outbreak fire with a wind velocity of 10 m/sec and Y1i is that with a wind velocity of 3.7 m/sec, the increase ratio percentage of spreading fire area (Fig) is derived from equation (4. 4).

$$Fgi = \log (Y2i/Y1i) = (C2i\text{-}C1i)\times N+(K2i-K1i) \cdots\cdots\cdots (4.4)$$

Fgi after 20, 40 and 60 minutes from outbreak fire become 2.28, 2.20 and 2.02, respectively. As a conclusion of this, it is more effective to consider how to

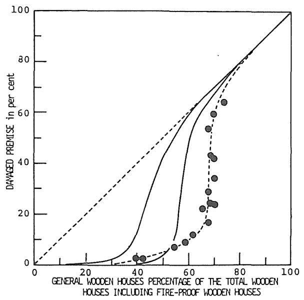

Figure 20 Relation between the crowded ratio and the burnt ratio.

control with diminishing of outbreak fire number in order to decrease of spreading fire area even though the wind velocity had been controlled artificially.

By defining the crowded ratio (Fci), under same mesh (i), by the ratio between the ordinary wooden houses and the fire-proof house, the burnt ratio (Fpi) under the any different mesh of Fci was determined. The relation between Fci and Fpi is shown in Figure 20. Where Fci and Fpi are defined as follows;

$$\mathrm{Fci} = \mathrm{Nw/Tw} \cdots\cdots (4.5)$$

$$\mathrm{Fpi} = \mathrm{Bw/Tw} \cdots\cdots (4.6)$$

respectively. Where Nw; number of the ordinary wooden house, Bw; number of the burnt house, Tw; total number of wooden houses.

As can be seen in Figure 20, those relations were revealed that Fpi tends to increase anomalously with Fci at around the value of 65 %. In other words, it is the fact that Fpi at the Fci value of 65 % is the critical mixing ratio.

On the bases of, analizing results of both the damage of outbreak fire and that of spreading fire, the most useful and effective ways of reducing damages are concluded as follows. The one is to reduce the number of outbreak fire and the another one is to make the mixing ratio of wooden houses at the crowed area to be less than 65 %. The former is to reduce the number of the totally destroyed wooden houses which is the foundamental of damage counterplan, on the other hand, the latter is to arrange the enviroment of crowded area of wooden houses, for example it promotes to make the area of fire-proof by means of increase of the number of parks, the green tract of land and so on. Moreover, the counterplan is required at the area having damage ratio. 5 that was shown in Table 4. It is also required especially at the area having (3) and (4) of the ground classification.

5. SUMMARY

In this study, the method of the earthquake risk assessment has studied according to estimate the earthquake damage such as destroyed houses, loss of lifvs and ground liquefaction, and indirect one such as damage by outbreak and its spreading fires. Summing up each damage, we introduced the evaluating method of the total damage by earthquake. And also, we are able to find the major factors which could be decreased the earthquake damage.

The main results from this study are given as follows.

(1) The results by means of the earthquake risk assessment in this study was enough to explain the area where suffered damage from past earthquakes in Japan. Therefore, it is concluded that this earthquake risk assessment method is very useful to planning the urbanisme.

(2) The main factors which related to the occurrence of various damage are listed as follows.

(a) The major damage factor on wooden houses is mainly affected by ground structures. Among those, it become clear that the damage probability at damage rank 3 is revealed especially very high with the ground classification 3 and 5. Although it is believed that the earthquake damage is relatively rare at the ground classification 6, based on this study it become clear to take place the small damage. This phenomena is very much consistent in the situation of present earthquake damage in Japan.

(b) The damage control factor at the man-made ground belonged to the ground classification 6 consists of both its form. Concerning on the former one, the difference of three times with the conversion of magnification factor is found by either cut-off or fill-up ground. On the latter one, the magnification factor with concrete protection from is reduced to about 0.6 times with comparing the value of unprotected sloped form. This is especially very clear for fill-up man-made ground.

(c) Concerning on fire damage, it is not necessary to have the high probability value at the area having high probability of totally destroyed damage of wooden houses discussed in the previous section (a). The area having large fire damage belongs to the ground classification 4 and in this area, the probability ever fire damage ranks should be the high probability value. Therefore, it is not necessary to conclude that the area of damage probability of wooden houses occurred the fire damage. As considering on the influence of spreading fire, it closely related to three factors, that is, the mixing ratio, the number of outbreak fires and wind velocity. Especially, the mixing ratio and the number of outbreak fires show the strong influence on the spreading area. The existence of critical mixing ratio became clear and its value is approximately 65%.

(3) As concerning on the future damage protection due to earthquake on the bases of the above considerations, the first of all, on the view of the protection of spreading fire damage, it is very important area belonged to the ground classification 4 as the intensify area. As that useful method, the number of outbreak fire should be reduced by the improvement of earthquake proof-wooden houses and it makes possible to reduce the risk of spreading fire by setting rate of fire-proof to be more than 65%. On the other hand, it is one of the useful damage protection plan by building concrete fence on the area of man-made ground that has been appeared by propelling of the city development at present.

In this paper, the earthquake risk assessment has been made by studying the estimating method of four damage topics and by synthesizeing on those. However, in order to make the comprehensive seismic risk assessment, it is necessary that we should estimate the damage due to the panic, the human behavior, and the life line. Moreover, on the view of fire damage case on destroyed wooden houses and fire damage have been treated. However, it would be required more complicate consideration to understand the actual fire damage areas. In future, we would like to continue further study on the bases of the above points.

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