Re-Evaluation of Seismic Intensity Distribution and Damage Characteristics of the 1945 Mikawa Earthquake

H. Nakai (1), M. Takemura (2), M. Sakamoto (3)

(1) *Chief, Nakashacreative Co., Ltd., h-nakai@nakasha.co.jp*
(2) *Professor, Nagoya University, takemura.masayuki@b.mbox.nagoya-u.ac.jp*
(3) *Associate professor, University of Hyogo, sakamoto@drg.u-hyogo.ac.jp*

Abstract

The Mikawa earthquake (M=6.8) occurred on January 13th, 1945. Mikawa Earthquake was known as an earthquake occurred just one month after the Tonankai earthquake (M=7.9) of December 7th, 1944, during World War Ⅱ, with heavy human casualties compared to housing damages. The data summarized by Iida in 1985, which had been used for discussing the damage by the Mikawa earthquake, was estimated using the maximum value of the damage of national level. However, it does not show damages in each municipality, which are hard to obtain now. In this study, first we re-evaluate the damage data of municipalities by using the data of Police Department, Aichi Prefecture of January 14, 1945. We also estimated the seismic intensity distribution in JMA scale. As a result, it became clear that seismic intensities in the Okazaki basin, which is alluvial lowland, are relatively larger than those of the Hazu hill zone, irrespective of the distance from the Fukouzu fault that ruptured in the Mikawa earthquake. This means the ground condition was the largest factor for the strength of seismic intensity and earthquake damages.

Second, to identify whether human loss was larger comparing to housing damages, we used the Nk value, which defines the number of the totally collapsed wooden houses divided by the number of the death. The average of Nk values is estimated to be about 10 for the 10 disaster inland earthquakes from 1891 to 1995 in Japan. The Nk value from the Mikawa earthquake was 3.1, which was smaller compared to other inland events. We assumed factors which affected the small Nk value as follows; School children and teachers who evacuated in group to the area during the war were killed by the earthquake and its Nk value was estimated to be 0.4. It is also important to consider the tendency that Nk values were smaller in the communities along the trace of the earthquake fault compared to those in the other communities. Thus, we examined the detail locations of totally collapsed wooden houses and death toll in Kota Village and the Katahara Town, where the surface fault breaks clearly appeared.

Keywords: Mikawa Earthquake, Damage Statistics, Seismic intensity distribution, Fukouzu fault, alluvial lowland

1. Introduction

The Mikawa earthquake (M=6.8) occurred on January 13th, 1945. The damage was 2,306 people died and 7,221 houses lost1).Mikawa Earthquake was known as an earthquake occurred one month after the Tonankai earthquake (M=7.9) of December 7th, 1944, during World WarII, with heavy human casualties compared to housing damages. There is no other earthquake with many dead people, such as the Mikawa Earthquake, that has no trace of the damage caused by the fire of the 1923 Great Kanto Earthquake or the occurrence of a large-scale secondary disaster such as the tsunami in the Tohoku region2).

There are various other studies and indications have been made on the Mikawa earthquake. For example, In Kadooka3), many children were lost due to the collapse of the temple's main hall by the earthquake, and it is estimated that more than 50 people were victims in the mass evacuation site. Takemura and others4) points out that the spread of alluvial deposits in the Okazaki Plain by the Yahagi River corresponds with the area of seismic intensity 7, and It is clarified that the difference in the underground structure sandwiching the boundary between the plain and the mountainous area is larger than the difference between the upper and lower faults. In Hayashi, 5) accounted for 83% of the 2,306 people died in 9 towns and villages (Meiji, Yokosuka, Fukuchi, Katahara, Sanwa, Anjo, Sakurai, Nishio, Yoshida), and the damage caused by the Mikawa earthquake was 20-30 km .He stated that he was concentrated in a narrow area on all sides, and cited the fact that numerous human damages occurred in the children of national schools who had been evacuated

from Nagoya City as a characteristic of the damage.
The all damage data on which these studies are based from Iida 1). Iida 1) referred to the Mikawa earthquake as a shallow inland earthquake, and stated that it was causing great damage locally due to uplift and subsidence of faults.

It was discussed there are many places with seismic intensity 6 in the Nishimikawa area, and the area that reached seismic intensity 7 extended to 6 towns and villages, and was found in the soft ground around the fault or in the basins of the Yahagi and Yahagi Furukawa rivers. It was reported that the number of casualties was 6,172, and the number of houses was crushed 48,087. In 14 villages were nearly annihilated. On the other hand, Takemura and Toraya 6) pointed out that the data of Iida 1), which was also used for the evaluation of the Tonankai earthquake, was incomplete. And they corrected Iida's data and evaluated the total collapse rate for each municipality to obtain the seismic intensity distribution. In the case of research on the Mikawa earthquake, when using the data from Iida 1), there are very few examples of researching damage data going back to the original. Therefore, in this paper, the roots of Iida 1) materials will be clarified as much as possible, data creation for each municipality, re-evaluation of seismic intensity distribution, and characteristics of the trends and damage will be clarified. In previous studies, we pointed out that the Mikawa earthquake was an earthquake which caused many deaths, and discussed the factors individually, such as topography, faults, and school evacuation. The contents are not necessarily quantified, and there remains sensory aspects.

On the other hand, Takemura6) defines Nk = total number of houses destroyed / number of deaths. As for damage earthquakes after Meiji period, with accurate damage statistics, Nk = 7 to 13 for normal earthquakes that are damaged by strong shaking. The purpose of defining the Nk value is that the destruction of houses is one of the major causes of death, and the total number of houses divided by the total number of deaths by the number of deaths considered to be caused by the destruction of houses. This is to show the percentage of deaths of one person. In this paper, the damage data for each municipality of the Mikawa earthquake is reconsidered based on the Nk value, and the problem of comparing the Mikawa earthquake with other inland earthquakes is examined. We will discuss quantitatively which of the various factors has a significant impact.

2. Organize data

2.1 Characteristics of Iida Data and its problems

Based on the data from Iida 1), here we reconsider the data for each municipality that will be necessary to review the seismic intensity distribution. Iida 1) includes “Table-5 Summary of Mikawa Earthquake Damage” and “Table-6 Mikawa Earthquake Damage Table by Municipality” as damage data.

There are several sources for the numerical basis of “Table-6 Damage Table by Municipality of Mikawa Earthquake”. In Iida 1), the corresponding symbols such as A, F, and H are defined for each material. Also shows the number of data cited from each material. The figures for municipalities are often based on materials published by municipalities. Furthermore, even the same municipality may be cited in “Table-6 Damage Tables by Municipality of Mikawa Earthquake” from multiple sources. Next, the counts in the “Table-6 Damage Table by Municipality of Mikawa Earthquake” are based on one or more of A, I, and K materials, but they are based on the count by municipality. It was not always the same as the values collected in. Therefore, Iida 1) has different data values, the count value in “Table-5 Summary of Mikawa Earthquake Damage” is the largest of the count values in A, I, and K. On the other hand, review the seismic intensity distribution, data by municipality is required. Therefore, Iida 1) organizes the survey data in “Table-6 Damage Table by Municipality of Mikawa Earthquake” and creates data by municipality. On the other hand, to review the seismic intensity distribution, data by municipality is required. Therefore, we organized Iida's “Table-6” and created municipal data.

The original documents confirmed in are A's Anjo City History 7), H's Hekikai Office Report Material 8), HT's Hazu Region Office Report Material 9), K's Aichi Prefectural Security Division Announcement Material 10), W's Wasurejinoki14).If we compare the values listed in these figures with those in “Table-6 Damage Tables by Municipalities of Mikawa Earthquake”, there are no errors. As indicated by the number of data in, it was K of Aichi Prefectural Security Division that data was published for almost all municipalities included in the damaged area. As mentioned at the beginning, Iida 1) used the maximum count value of the A, I, and K materials for the figures for the damage caused by the Mikawa earthquake, 2,306 people died, and 7,221 houses lost. Iida [1)]'s "Table-5 Summary of Mikawa Earthquake Damage" is a statistic that is mainly used as the damage of the Mikawa Earthquake. Hereinafter, it is referred to as "general data". In the general data, since the maximum value of the district count value is used, there is a county that is different from the value calculated for each districts from the value for each municipality. On the other hand, to create a seismic intensity distribution map, data by municipality is required, so the data by municipality is reconstructed from the data in based on the data surveyed uniformly by one organization.

In this paper, we focus on I, K, and M, which have many data. About M by Miyamura, it was probably due to personal communication to Iida and we didn't understand the reason. Therefore, we created municipal data using two types of data, I by Iida and K by Aichi Prefectural Security Division. In the following, they will be referred to as UI and UK as unification Iida data and unification security section data, respectively, and their creation methods will be described in the next chapter. Focusing on the UI where the aggregate value of the data was large, it is shown in Table 1 for comparison with the general data. Looking at Table 1, in Chita, Hoi, and Atsumi counties, the total and half collapse numbers of non-house in the general data are significantly larger than the data UI.

The total number of the totally collapsed wooden houses in Chita-gun, Nukata-gun, and Atsumi-gun is larger in the general data. As for the number of fatal injuries in Hekikai-gun, the number of deaths was 691 in the data UI, but 851 in the general data, and the number of injuries was 1023 in the data UI, whereas in the general data, 1,134 both are more than 100 people. As for the general data of Hekikai-gun, the maximum value of county values is used, but the material on which the values are based is not written in Iida [1)]. As for the general data, Chita, Hoi, and Atsumi counties, it is written that the Anjo City History [7)] are quoted as they are. Therefore, when we examined Anjo City History[7)], the county count was quoted from Aichi Prefectural Statistical Document[10)].

This time we went back to the original, but there was no data to show the unit of municipalities other than the count by county unit. For Nukata-gun, it should have taken the larger of the counts of Anjo City History [7)] and Aichi Prefectural Security Division's announcement materials [10)], but only the total and half-collapse of non-residential houses are small. The data from a certain Aichi Prefectural Security Division announcement data[10)] is adopted. This point is contrary to the basic policy of taking the larger one in the county counts stated in Iida [1)]. The possibility of selection error is also conceivable.

Table 1 – Data UI count data and general data by Iida [1)]

District・City	Dead		Injured		House				Non-House				House	
					Complete destroyed		Partially destroyed		Complete destroyed		Partially destroyed		Collapse rate (%)	Half-collapse rate (%)
	UI	General	UI	General	UI	General	UI	General	UI	General	UI	General		
Nagoya	8	8	19	26	70	72	459	460	114	141	88	562	0.1	0.5
Toyohashi	1	1	4	4	0		39	39	5	5	3	3	−	0.1
Handa	12	12	5	5	124	124	333	333	7	31	79	79	1.2	3.2
Chita	0	0	2	2	32	33	388	388	12	109	39	193	0.2	1.6
Hekikai	691	851	1023	1134	2829	2829	6950	6950	4773	4812	7195	7485	7.9	19.3
Hazu	1163	1170	2462	2520	3693	3693	6180	6388	3447	3468	5595	5751	21.2	36.7
Nukata	25	26	18	18	27	41	14	81	16	16	6	6	1.6	3.2
Hoi	237	237	151	151	333	333	1443	1443	88	515	243	770	10.4	45.1
Atsumi	0	1	−	6	59	92	459	459	1	83	0	261	1.8	9.1
Aichi	0	0	0	0	2	2	9	9	0	−	0	−	0.0	0.0
Nakajima	0	0	0	0	2	2	2	2	5	5	11	11	0.0	0.0
Haguri	0	0	0	0			3	3	2	2	3	3	−	0.0
Total	**2137**	**2306**	**3684**	**3866**	**7171**	**7221**	**16279**	**16555**	**8470**	**9187**	**13262**	**15124**		

2.2 Data by municipality

The data UI and the data UK described in the previous chapter will be described in this section because data by municipality is required to create a seismic intensity distribution map.First, in creating the data UI, it was stated that [I] was the data that Iida confirmed at the time of writing the paper, so We decided to organize around this data. For the municipalities without I in Table -6 of Iida [1)], the data UI for each municipality was created by identifying which data Iida adopted by back-calculating from the distribution maps of the total and half collapse rate in Figures -11 and -12 of Iida [1)]. For municipalities where I is not listed in Table 6 of Iida [1)], Iida [1)] calculates the data that Iida uses by calculating backwards from the distribution map of the total and half-collapse rate in Figures 11 and 12 of Iida [1)]. By creating a data UI for each municipality.
The figures for non-residents, dead, and injured were taken from data cited in the same data used in Figures

11 and 12 of Iida 1). For Shinkawa-cho and Asahi-mura in Hekikai-gun, the data used for the total collapse rate and the half collapse rate differed, so for non-houses, dead and injured persons, the data with the larger value was adopted. All items other than I in the classification were calculated from the total collapse rate and half collapse rate of Figures-11 and 12 of Iida 1). If I and other data match, note that in the remarks.

Next, we explain a method for creating data UK. Focusing on the data K by the Aichi Security Division, whose survey data has been most uniformly identified from the list of materials collected by Iida in We decided to create data UK by municipality. K is the data of the Aichi Security Division on January 18, but since the data of the Aichi Prefectural Security Division on January 14 was found in the subsequent data survey, this data will be referred to as 14K hereinafter. Data UK was created using K and 14K. Specifically, Nagoya was not in K, but it was listed in 14K, so we took 14K data. In general, damage is considered to increase with the number of days, but for the municipalities where the 14K data is larger than K, the 14K value was used. When the data UI created in this way is compared with the data UK, the UI values for all items are larger in all municipalities.

Table 2– Data UI and UK: Number of Deaths and the Number of Deaths Related to the Evacuation of Children

Municipalities	Present municipalities	Seismic intensity	Number of dead		Evacuation of School		
			DataI	DataK	School	Students	Teachers, etc.
Yoshida-Town	Nishio-City	6+	106	87	Enishi	8	1
Takahama-Town	Takahama-City	6-	56	31	Horita	9	7
Takaoka-Village	Toyota-City	6-	35	2	Sugimura	28	2
Oohama-Town	Hekinan-City	6+	25	16	Horita	9	

*The seismic intensity was calculated using the data UI. Data related to the evacuation of school children are based on data from Iida 1).

For example, when we look at the difference in the number of deaths between Data UI and Data UK, we find that Iida includes school-children who died in evacuation areas and teacher, but does not include the Aichi Security Division. Taking Ohama-town in Table 2 as an example, the number of deaths from UI was 16 while that from UK was 25. The number of deaths among evacuees from school children mentioned in Iida 1) is nine, and it is assumed that the UK does not include these 9. Such cases have been confirmed in Takaoka Village and other places.

3. Discussion

3.1 Re-Evaluation of Seismic Intensity Distribution

The number of buildings in the denominator is important for determining the total collapse rate. In general, the number of buildings is often unknown, the number of households is used as the denominator assuming one household and one dwelling 2). Iida 1) makes such an assumption. However, the basis for the number of households used is not clear and unquoted.

In this paper, we will use the results of the national census. In Japan, census has been regularly conducted since 1920. Therefore, in this paper, the number of households by municipality is used as the denominator when calculating the total collapse rate Y based on the survey results conducted at the nearest time before the earthquake. As the national census closest to the year of the Mikawa earthquake, 1945, there is a survey in 1940.In Takemura and Toraya 6), the population is based on the results of the population survey in 1944, and in areas where the number of households fluctuates by more than 20% from the population in 1940 and 1944, mainly based on the number of ordinary households from the population census in 1940, the number of households in 1944 is adjusted by the ratio of population to population.

In Takemura and Toraya 6), the subject area in Aichi was five towns and villages, but in the present subject area, there were two cities and towns, Handa City and Kariya Town. In these regions, an increase in the number of personnel accompanying the construction of new military plants is thought to have had a major impact on the population. The same evaluation method was used for seismic intensity evaluation in order to be consistent with the rearrangement of the damage statistical data of the Tonankai Earthquake by

Takemura and Toraya [6].Takemura and Toraya[6] adopted a method of calculation based on the total ulcer rate Y and using the total half collapse rate h as an auxiliary. shows the relationship between seismic intensity, total ulcer rate Y and total half collapse rate h. The main points of the procedure of seismic intensity evaluation by Takemura and Toraya [6] are as follows.

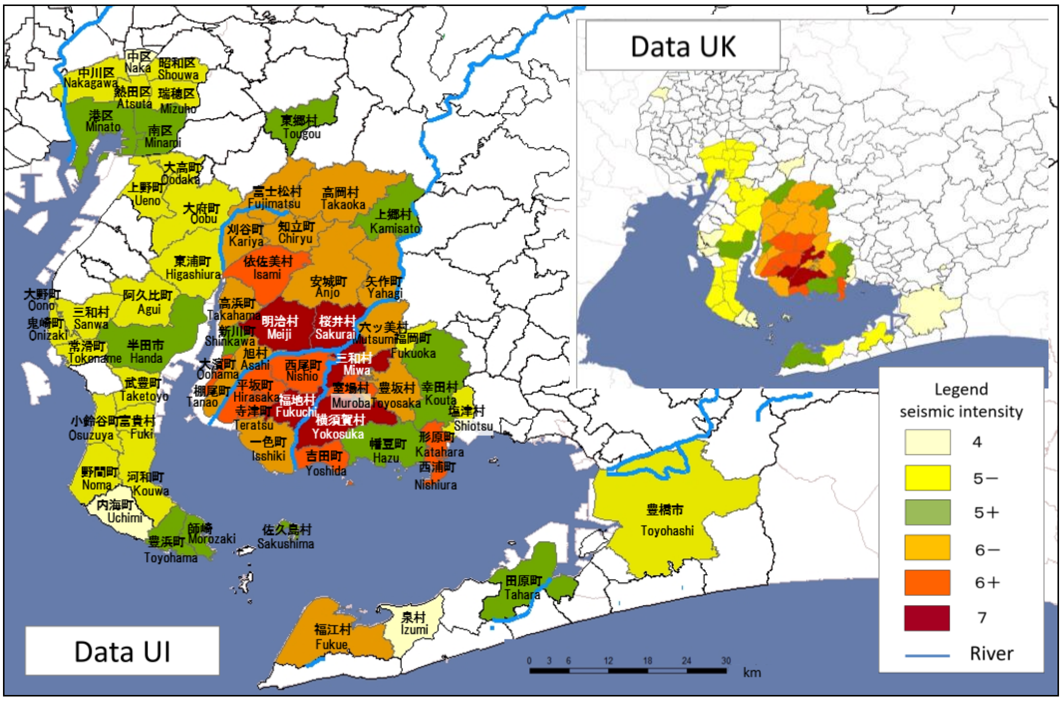

Figure 1 Seismic intensity distribution map of Integrated Iida Data UI and Integrated Security Division Data UK (upper right)

(1)Seismic intensity shall be 4 or higher at all points where damage is reported. applies to those regions.
(2) First, a total collapse rate Y with a seismic intensity of 7, 6 +, 6 −, 5 or less is determined. However, the seismic intensity is raised by one rank when the judgment by the total half crush rate h is larger than two ranks.
(3) When the determination in (2) is 5 or less and the total half collapse rate $h \neq 0\%$, the seismic intensity of 5 + or 5 − is determined depending on whether h is 1% or more or less.
(4) Even in the case of the total half collapse rate $h = 0\%$ (Corresponding to seismic intensity 4), it is assumed that the seismic intensity is 5 − if there is total collapse of non-dwelling house or death.

As can be seen from the above procedure (3), the total half crush rate h is mainly used to assist the evaluation at a seismic intensity of 5 or less.

The distribution of the total collapse rate was obtained from the integrated Iida data UI, and the seismic intensity distribution over the Mikawa earthquake damage area was estimated based on that value. The results are shown in Figure 1. Also, since the integrated security section data UK is suitable for grasping the whole picture as unified data by one organization, the seismic intensity distribution map by the data UK is shown in the upper right of Figure 1. As a result, the seismic intensity in many areas of Data UI and Data UK is the same. There are some differences in seismic intensity in Meiji Village, Sakurai Village, Fukue Village, etc., but even in municipalities where the seismic intensity does not match, explain the difference is about one step.

3.2 Damage assessment of past earthquakes by Nk value

As described in Section 1, many of the previous studies have pointed out the large number of deaths from the Mikawa earthquake, but there are few that quantitatively discuss the causes. Here we will examine this point in detail and clarify the points which are considered as problems. For the summary of the damage caused by the Mikawa earthquake, we used the data of counties by county in Table-5 of Iida [1)], which is usually used. On the other hand, as Iida [1)] counts by county, 2,306 deaths and 7,221 total collapsed houses cannot be returned to data by municipality, as mentioned above, the data UI used for each municipality described in Section 2. Takemura [2)] pointed out that the Nk value is 7 to 13 for normal earthquakes that are damaged by strong shaking, compared to the damage earthquakes after the Meiji period with accurate damage statistics. This shows that, on average, one person died when 10 houses were crushed. On the other hand, when a special event such as a fire or tsunami occurs, the number of deaths increases rapidly and the Nk value decreases. Table lists the results of Takemura[2)] with information on the 2011 Great East Japan Earthquake. The deficits in Table indicate earthquakes that are likely to have a significant impact on damage caused by special events such as fires and tsunamis.

According to Takemura[2)], the total number of houses here indicates the number of houses that were completely lost due to burning, runoff, burial, etc. As Takemura [2)] pointed out, Nk = 2.8 in the Great Kanto Earthquake in 1923, when major fires occurred in Tokyo and Yokohama, and Nk = 4.0 in the 1927 Kita-Tango Earthquake in 1927, when there was a major fire in Mineyama-cho, Kyoto. The 1896 Meiji Sanriku earthquake, which was killed by many people in the Great Tsunami, was Nk = 0.4, the 1933 Showa Sanriku earthquake was Nk = 1.3, the 1993 Showa Sanriku earthquake was Nk = 1.3, and the 1933 Hokkaido Nansei-oki earthquake Has Nk = 2.6. According to the 2011 Great East Japan Earthquake, according to the materials released by the Emergency Disaster Security Headquarters, National Police Agency as of December 10, 2013, the number of dead and missing persons was 18,526, and the total number of destroyed houses was 126,220, Nk = 6.8. In recent years, the definition of total collapse of buildings has been greatly mitigated. As pointed out by Takemura[8)], normal damage earthquakes after 2000 can be as high as Nk = 30-50. It can be said that it is a small value. According to Moroi / Takemura [17)], the numerical value that is usually said to be the total number of earthquakes in the Hyogoken-Nanbu Earthquake represents the destruction. As Takemura[2)] points out, since the wreck corresponds to almost half-collapsed, the value is halved assuming that the total number of crushed = half-collapsed. In recent years, there are many cases where complete collapse is written as complete destruction due to the tendency of the use of a series of Kanji starting with the current Kanji.

The Mikawa earthquake is the ninth from the top when the major damage earthquakes since Meiji are arranged in descending order, and the number of deaths is not particularly high compared to other earthquakes. On the other hand, as noted earlier when focusing on the Nk value, the Mikawa earthquake has the smallest Nk = 3.1 among earthquakes whose main cause of damage is ground motion. In other words, the main cause of damage is damage to houses due to vibration, and the Nk value for earthquakes that are not affected by fire or tsunami is Nk = 7-13, while the conditions are similar, but Nk = 3.1 for Mikawa earthquake. Is a small value. This value is comparable to Nk = 2.8 of the Great Kanto Earthquake where a large fire broke out. From the above, the essence of the problem pointed out that the number of deaths due to the Mikawa earthquake is large is not that the total number of deaths is large, but that the Nk value is small, that is, the number of deaths is large for the total number of crushed houses I understand. To investigate this cause, this paper focuses on the fact that the Mikawa earthquake is different from other earthquakes and examines whether each factor can cause the Nk value to decrease.

4. Factors affecting the number of deaths

When the background selected for each item is added, the Tottori Earthquake in 1943 was also an earthquake during wartime, but the Mikawa Earthquake was the only one that occurred after the effects of evacuation of school children became significant. And, there are several other earthquakes in which surface earthquake fault appeared on surface, and the Mikawa earthquake was the only earthquake which satisfies all three features. The effect of these factors on the number of fatalities is examined by focusing on the Nk value mentioned above. Follwing are the results.

4.1 The impact of war

Concretely, air raids, conscription, and evacuation of schoolchildren were examined as the effects of the war. First, check whether damage caused by air raids may have been counted as earthquake damage by mistake. Regarding air raids, detailed damage records of the earthquake and air raids are left in 'Investigation on the damage caused by air raids in the Great East Japan Earthquake' 10) of Aichi Prefectural Security Division. Among them, the damage caused by the earthquake can be confirmed to be the data of the Security Division organized Section2. As for the damage caused by air raids, the address and the number of damaged houses, and the number of dropped bombs are written in detail, and the items of air raids and earthquake damage are clearly separated, it is unlikely that the data are confused. However, if the effects of the air raids were significant, it is conceivable that people who lost their houses due to the air raids were forced to live in temporary houses with poor earthquake resistance, or that more people than usual lived in neighboring relatives or neighbors' houses.

Therefore, the air raids described in 'Investigation on the damage caused by air raids in the Great East Japan Earthquake' 10) from December 7, 1944 to January 23, 1945, which are estimated to have been relatively large with more than 20 aircrafts. Table shows that air raids around Nagoya started intensively immediately after the Tonankai Earthquake.The areas damaged by air raids were both in the towns and villages around Nagoya City and Toyohashi City. The location of the damaged area is shown in Fig. 1. In Nagoya City, damage due to air raids has occurred, but in the area where many deaths occurred due to the Mikawa Earthquake, it is clear that there was no damage to houses or the effects of the dead by air raids. From these facts, it can be said that the damage by air raids was located in the vicinity of the damaged area by the Mikawa Earthquake, and the direct effect of air raids on the earthquake damage was very limited.

Next, we consider the damage to children evacuated from school. On this point, Iida 1) and Tsunooka 3) investigated, and it is known that the temple of evacuation place collapsed during sleeping and many school children disappeared. In second section, two types of data are prepared: data UI which recounts the data by the municipality of Iida 1) on the data by the municipality in the damage statistics, and data UK which is the totaling value of Aichi security division. As a result, the number of fatalities is compared between the data UI and the data UK.The data UI shows some municipalities with 10 to 20 fatalities. The data UK does not include the number of fatalities due to the evacuation of school children, but it is speculated that it may be included in the data UI.The difference is considered to correspond to the number of deaths due to evacuation of school children, which is 175. When the Nk value is calculated by subtracting 175 deaths from the death toll of 2,137 in the data UI including the death toll by the evacuation of school children, Nk = 3.6. The value of 0.5 was larger than that of Nk = 3.1 for the Mikawa earthquake in Table 5.

Next, the number of deaths due to evacuation of school children investigated by Iida 1) is examined. Table 2 summarizes the results of the survey conducted by Iida 1) and the population, seismic intensity and number of fatalities by town and village based on the data UI . According to Aichi Prefectural Education History Volume 4, 11), "It was decided to be persons in total of 37,179 persons of 82,349 persons of the group evacuation applicant and 45,170 persons of the relation evacuation applicant. It was decided that 60% of the group evacuees should evacuate to Aichi Prefecture, and the remaining 20% each to Gifu and Mie Prefectures."In the case of group evacuation, about 22,308 children, or 60% of the total, will evacuate, and the number of relatives will be increased. According to the list of evacuation sites for schoolchildren in Nagoya City 11) in the history of education volume 4 11), 6,354 evacuees lived in the Nishimikawa area (Fig. 1) where the seismic intensity was lower 5 or more. A comparison of the survey results between the list of evacuation destinations for school children in Nagoya City 11) and those in Iida 1) shows the names of schools with the same evacuation destinations in Table 2. As the result, the survey result of Iida 1) seems to have high reliability, because most municipalities of the evacuation destination agreed. According to the inconsistent evacuation plan, Sugimura Kokumin School was evacuated to Takayama City, Gifu Prefecture and Horita Kokumin Gakko to Tanao Town, Shinkawa Town and Takahama Town in Aichi11). Taking Oi National School as an example, there were many school children who were evacuated to Kanie City until November when the earthquake occurred, but they complained of louse problems and skin diseases because of the humid region, and it is known that they moved to Miwa Village where the Yahagi River is clean in December3). Thus, it is possible that the evacuees moved in a group from the first evacuation area to another area for some reason.According to a survey conducted by Iida 1), the number of deaths among school children is known to be 99. In addition, the 111 -death toll of those involved in evacuation, including Teacher, dormitory mothers, and their families is 12. When the Nk value is calculated by subtracting the number of fatalities associated with evacuation from the number of fatalities associated with evacuation of school children (2,137-111) from the number of fatalities associated with evacuation of school children (UI), Nk = 3.5. The value of 0.4 was larger than that of Nk = 3.1 for the Mikawa earthquake in Table 5. In other words, it is inferred that the Nk value was lowered by about 0.5 to 0.4 due to the influence of the number of deaths related to evacuation of school children.In "Records of the evacuation of school children" 11), there is a description such as "Some families had two kitchens for the children of nepotism, while others had 15 people from three families in one family."and it is possible that many people gathered in one place and the death toll increased when the house collapsed. Although not included in the above discussion, it is possible that the Nk value was further reduced by increasing the number of fatalities if the data UI included the damage of nepotism evacuees.

4.2 Relationship with surface earthquake faults

In Matta and Kimata 12), the area where surface earthquake fault appeared in the Mikawa earthquake had many fatalities near fault. Surface earthquake fault in this paper is called Fukouzu fault in the southeast and Yokosuka fault in the northwest 13). The towns and villages in which the surface earthquake fault appeared are Katahara town, Kota village, Toyosaka village, Yokosuka village, Muroba village, and Miwa village from Figure 1, and among them, the Fukouzu fault, in which the surface earthquake fault appeared especially clearly, passes through Katahara town, Kota village, and Toyosaka village.

Table 3 shows the areas damaged in descending order of the number of fatalities. The table on the right shows the descending order of Nk value, that is, the descending order of the number of fatalities for the total number of houses. Towns and villages where surface earthquake faults appeared are colored in gray, and areas with seismic intensity of 7 are indicated in red. According to the table on the left, the highest number of fatalities was 325 in Meiji village, followed by regions with seismic intensity of 7-6 upper. These areas belonged to alluvial lowland and coastal lowland, and the ground was soft. According to the table on the right, the Kota and Takaoka with Nk = 1.1 have the lowest Nk values. Kota and Takaoka , whose seismic intensity is 5 upper and 6 lower, respectively, belong to the hilly region of Hazu mountain range, and are not the region of seismic intensity 7.

Table3.shows the comparison of the top ten tables. Surface earthquake faults appeared in three towns and villages in the left table, while they appeared in five towns and villages in the right table. Especially, taking Kouta Village as an example, it is the 14th from the top in the left table, but the first in the right table. If we look i detail, the number of fatalities becomes 25 with 27 houses completely destroyed, and when one house is completely destroyed, one person dies. Matta and Kimata12) indicated that there are many fatalities in the vicinity of the surface earthquake fault, and it seems to be more appropriate to consider that there are many fatalities but also small number of completely destroyed houses, when the example of Kouta town is observed. Looking at the top three regions in the table on the right, it can be seen that the Nk values are very low in Kota, Takaoka and Katahara villages. In Takaoka Village, 30 of the 35 deaths were related to the evacuation of school children, and it is thought that the death of many school children at one site, such as a temple where they were evacuated, was the cause. The Nk value of Takaoka village is Nk = 7.6, which is almost the usual value except for the number of fatalities related to evacuation. Kouta village and Katahara town are towns and villages near Fukouzu fault, and the clear fault and crack are found. Therefore, the Nk values of the Mikawa Earthquake are calculated, except for the towns and villages where the gray-colored surface earthquake fault appeared in Table 3. The Nk value is 3.9, which is an increase of 3.1 from Nk = 0.8 for the Mikawa earthquake in Table 5. This suggests that the occurrence of surface earthquake faults is one of the factors that decrease the Nk value of the Mikawa earthquake.

In Takaoka Village, 30 of the 35 deaths were related to the evacuation of school children, and it is thought that the death of many school children at 1 site, such as a temple where they were evacuated, was the cause. The Nk value of Takaoka village is Nk = 7.6, which is almost the usual value except for the number of fatalities related to evacuation. Kouta village and Katahara town are near Fukouzu fault, and the clear fault and crack are found. Therefore, the Nk values of the Mikawa Earthquake are calculated, except for the towns and villages where the gray-colored surface earthquake fault appeared in Table 3. The Nk value is 3.9, which is an increase of 3.1 from Nk = 0.8 for the Mikawa earthquake. This suggests that the occurrence of surface earthquake faults is one of the factors that decrease the Nk value of the Mikawa earthquake.

Table 3 List of towns (T) and villages (V) with the highest death toll (left) and the lowest Nk value (right)

No.	Town,Village	Seismic intensity	Death toll	Total collapsed houses	Nk
1	Meiji−V	7	325	1039	3.2
2	Yokosuka−V	7	275	760	2.8
3	Katahara−T	6+	233	319	1.4
4	Fukuchi−V	7	229	450	2.0
5	Miwa−V	7	196	544	2.8
6	Sakurai−V	7	179	435	2.4
7	Nishio−T	6+	176	760	4.3
8	Yoshida−T	6+	106	422	4.0
9	Isshiki−T	6−	77	283	3.7
10	Teratsu−T	6+	58	132	2.3
11	Takahama−T	6−	56	155	2.8
12	Takaoka−V	6−	35	38	1.1
13	Oohama−T	6+	25	241	9.6
14	Kouta−V	5+	25	27	1.1
15	Anjo−T	6−	21	195	9.3
16	Hirasaka−T	6+	20	228	11.4
17	Muroba−V	6+	18	77	4.3
18	Yahagi−T	6−	16	117	7.3
19	Mutsumi−V	6−	13	119	9.2
20	Isami−V	6+	12	234	19.5

No.	Town,Village	Seismic intensity	Death toll	Total collapsed houses	Nk
1	Kouta−V	5+	25	27	1.1
2	Takaoka−V	6−	35	38	1.1
3	Katahara−T	6+	233	319	1.4
4	Fukuchi−V	7	229	450	2.0
5	Teratsu−T	6+	58	132	2.3
6	Sakurai−V	7	179	435	2.4
7	Yokosuka−V	7	275	760	2.8
8	Takahama−T	6−	56	155	2.8
9	Miwa−V	7	196	544	2.8
10	Toyosaka−V	6−	8	23	2.9
11	Shiotsu−V	5−	1	3	3.0
12	Meiji−V	7	325	1039	3.2
13	Nishiura−T	6+	3	11	3.7
14	Isshiki−T	6−	77	283	3.7
15	Yoshida−T	6+	106	422	4.0
16	Muroba−V	6+	18	77	4.3
17	Nishio−T	6+	176	760	4.3
18	Asahi−V	6−	2	14	7.0
19	Yahagi−T	6−	16	117	7.3
20	Chiryu−T	6−	5	42	8.4

*Areas where surface earthquake faults appear are indicated by gray lines, and areas with seismic intensity of 7 are indicated by red letters.

4.3 Comparison with the 1944 Tonankai earthquake and other factors

According to the previous mentioned studies on the Nk value, it was found that the Nk value increased by 0.4 and the surface earthquake fault effect increased by 0.8 due to the effect of school children evacuation. If these effects are assumed to be independent and reflected in Nk = 3.1 of the Mikawa Earthquake, Nk = 4.3. However, the main damage factor is vibration, and the average of Nk value of 9 inland earthquake without fire and tsunami is 8.8, and when the standard deviation is calculated, it is ± 1.8, which is a significantly small value in comparison with the value. In the above examination, Mikawa Earthquake and the 1896 Rikuu Earthquake are excluded.The Rikuu earthquake is an earthquake in the evening, and especially, it is known that the Nk value is increased by the escape of people in the outdoor by the earthquake of about 30 minutes before the main shock [14)]. Then, the effect of Tonankai Earthquake which occurred about 1 month before Mikawa Earthquake is examined, when other effects are considered. The Tonankai earthquake occurred at 1:36 PM on December 7, 1944, about 1 month before the Mikawa earthquake on January 13, 1945. Takemura and Toraya [6)] arranged the damage data of Tonankai Earthquake which corrected the error of data of Iida [1)]. According to it, 18,143 houses with complete ulcer and 36,638 houses with half ulcer were damaged.

Regarding the seismic intensity distribution of the Tonankai earthquake, Takemura and Toraya [6)] compiled the damage statistics data of the 1944 Tonankai earthquake and corrected the erroneous seismic intensity distribution data and compiled the seismic intensity distribution map (Figure2: Right). As can be seen from the figure, in the Niahimikawa region, the seismic intensity is 7 in Fukuchi Village in the Yahagi Furukawa basin, and the seismic intensity is 6 or higher in the downstream Isshiki town and Yoshida town. There is compare the seismic intensity distribution map of the Mikawa earthquake with the seismic intensity distribution map of the Takemura-Toraya [6)] Tonankai earthquake (Figure 2). The magnitude of the seismic intensity is different because the location of the epicenter is different, but the damaged area of the Mikawa earthquake surrounded by the red dotted line in the figure is high in the Okazaki Plain and Yahagi River basin, the area surrounded by the red solid line is Seismic intensity is low in the hilly area around Kouta Village. Thus, the common feature seen in both shows that ground conditions have a great influence on seismic intensity and damage. And, Most of the Nishimikawa area, which was severely damaged by the Mikawa Earthquake, had a high seismic intensity. In these areas, it was found that the damage was expanded by the larger shaking 37 days after the Tonankai earthquake. The damages -in Aichi Prefecture in the Tonankai Earthquake of Takemura and Toraya [6)] was the total number of collapsed houses of 6,943 and the number of fatalities was 435. The Nk value gives Nk = 15.9. It is found that Nk = 3.1 of the Mikawa earthquake is much smaller than the standard value 7 ~ 13 of the Nk value indicated above. The Tonankai earthquake occurred during the daytime when people were active. Many of them carried out air defense training during the war, and December 7 was the day before the anniversary of the outbreak of the war, and in addition, many of them were found to have engaged in outdoor activities such as work service 6). In addition, the Tonankai earthquake was a trench type earthquake, and the hypocenter was far in comparison with the inland type earthquake, and the initial tremor duration was longer for that reason, and the whole shaking was comparatively slow, and it seemed to be easy for the indoor people to escape. On the other hand, 3:38 am on January 13, the Mikawa Earthquake occurred.It, -was midnight in the middle of winter. It is considered that the time of sunrise during this period was late and therefore the time of awakening was also late. "Two days ago, an earthquake with a seismic intensity of 3 to 2 occurred several times a day. You can't go inside the house. However, he did not enter the house, and stayed out of the house until the evening. After a day, 13 nights, it is very quiet." 14). It is highly possible that the "foreboding" mentioned here is not a foreshock of the Mikawa Earthquake but an aftershock of the Tonankai Earthquake. It is considered that there were many people who slept soundly in the house without any worries, because the aftershock which continued until the previous day was settled on the night of 12th. It is inferred that people who slept soundly indoors did not have time to evacuate because of the rapid shaking immediately after the occurrence of the inland earthquake.

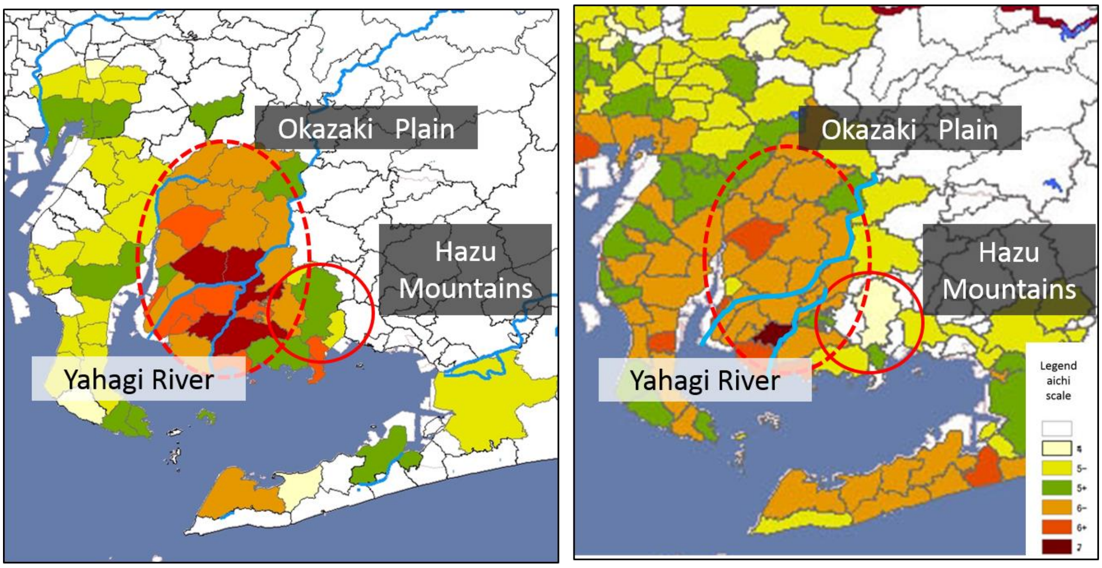

Figure. 2 Comparison of seismic intensity distribution between Mikawa earthquake (left) and Tonankai earthquake (right) due to Takemura and Toraya6)

Figure 2 shows the relationship between the time of occurrence and the Nk value of an inland earthquake with vibration as the main damage factor. Seasons are expressed in different colors. It can be seen that many earthquakes are concentrated around 5 AM or 5 PM. Around 5 PM is the time when people are active. On the other hand, as an earthquake with relatively early morning, there is Kitaizu earthquake (4:02 AM) and Akita Senboku earthquake (4:59 AM), but it is not midwinter in Kitaizu and Akita Senboku since they are in March and November. On the other hand, the Hyogo-ken Nanbu Earthquake, like the Mikawa Earthquake, occurred in January, but it occurred before 6 AM, and many people were trying to wake up, not during the sleeping time like the Mikawa Earthquake. Only the Mikawa earthquake occurred at 3 AM and midnight in the middle of winter, indicating that the earthquake occurred at the time when many people were sleeping. That is to say, the temporal and seasonal factors of midnight in the middle of winter delay the evacuation action of people from the completely destroyed house, and it is difficult to quantify them, but the possibility of becoming a factor to reduce the Nk value of Mikawa Earthquake is considered.And,It is also conceivable that buildings are more likely to collapse due to multiple earthquakes, or that the time taken to collapse becomes shorter, and it is also conceivable that the number of fatalities increased due to a delay in escape.

5. Conclusion

As a result of the survey research of the Iida 1) data, the numerical value generally used as the damage of the Mikawa Earthquake was the summary of the largest value of the county totaling the investigation data of Iida, and it was proven that there was a region in which the breakdown in the municipality unit could not be returned. Therefore, data by municipality was created using the integrated Iida data UI and the integrated security section data UK. Comparing those two datas, it was found that the number of deaths in the data UK did not include school evacuation. On the other hand, there was no significant difference in seismic intensity distribution, and a seismic intensity distribution map was created using the data UI. As a result, the seismic intensity was higher in the Okazaki Plain and the Yahagi River basin, which are alluvial lowlands, and low in the Hazu Mountains and other hilly areas. This indicates that the geographical features and ground conditions are more strongly correlated with seismic intensity than the distance from the epicenter. As for the damage, both the number of complete ulcers and the number of deaths are high in Okazaki Plain, where the seismic intensity is expected to be high.

In addition, by comparing the seismic intensity distribution map with that of the Tonankai Earthquake in Takemura, Toraya 6), it was found that the effects of seismic intensity and damage due to the ground were similar to those of the Tonankai Earthquake. The towns and villages where more than 100 people died were those with a seismic intensity of upper 6 or more, and the Nk value of the number of dead and totally destroyed tended to decrease in all areas.

Conventional, Mikawa earthquake is said to be an earthquake with many fatalities. This paper focused on the relationship between the number of completely destroyed houses and the number of deaths, and analyzed that the number of deaths is larger in proportion to the number of completely destroyed houses. The features were clear through the examination using the Nk value for the quantitative examination. The Mikawa earthquake was Nk = 3.1, and it was small in spite of the fact that the main cause of damage was the earthquake of vibration. This value is equivalent to Nk = 2.8 of the Great Kanto Earthquake in which a big fire occurred. Then, this paper examines the cause of small Nk value in the Mikawa earthquake from the viewpoint of the difference from the usual earthquake.

Among the events caused by the war, the effect of evacuation of school children, which can be expressed by the Nk value, was equivalent to 0.4 in the Nk value, and excluding the effect, Nk = 3.5. Nevertheless, the result was small compared with the value of Nk = 10, which is the usual value of earthquake. It was found that air raids and conscription did not significantly affect the Nk value. Other factors that could not be quantified were the influence of the evacuation of relatives, the occurrence of the Tonankai earthquake a month ago, and the occurrence time was midnight in the middle of winter.

Next, the region where surface earthquake fault appeared was examined. When the Nk values were arranged in descending order, it was found that Kouta village and Katahara town were arranged in the upper order, and these areas were the areas where the ground was comparatively hard and surface earthquake fault appeared though the seismic intensity was smaller than 7. In short, this paper shows that damage occurs poleward in the vicinity of fault even in the region where ground is good in the hilly part, and it suggests that examination considering features of swinging in the vicinity of fault, effects of fault displacement, and ground deformation is necessary. The Nk value of the Mikawa earthquake was calculated to be Nk = 3.9, which is an increase of 3.1 from Nk = 0.8 of the Mikawa earthquake, except for towns and villages where the surface earthquake fault appeared. It was considered that the appearance of the surface earthquake fault might be related to one of the factors to decrease the Nk value of the Mikawa earthquake.

It is necessary to advance the examination from various perspectives; such as comparing the factor in which the damage expanded in the vicinity of surface earthquake fault from shaking, fault displacement, distribution of the more detailed Nk value in proportion to the distance from the fault, difference of the damage of top board and bottom board which has been said for a long time, earthquake in which other surface earthquake fault appeared. We hope that this study will be one of the clues to elucidate the mechanism of damage expansion near surface earthquake faults.

6. Acknowledgements

We would like to express sincere–gratitude to Nakashacreative Co., Ltd for warm support to conduct researches. We would also like to thank to Mr.Shinji Tahara (Nakashacreative Co., Ltd) who helped with proofreading of the manuscript.

7. References

[1] Iida Kumeji (1985): Seismic damage and seismic intensity distribution of the Mikawa earthquake on January 13, 1945. Selected Papers by Prof. K. Iida, 571-668.

[2] Takemura Masayuki (2008): Earthquake and Disaster Prevention-From Elucidation of Shaking to Seismic Design, Chuko Shinsho, pp.236.

[3] Kadooka Takao (1990): School children group evacuation and Mikawa earthquake, mental scientist, pp.193.

[4] Takemura, Moroi, Yashiro (1998): Characteristics of strong ground motion from the viewpoint of the damage of the inland shallow earthquake after the Meiji Era-Conditions for the occurrence of seismic intensity 一, Earthquake, 2nd Report, Volume 50, 485-505.

[5] Hayashi Yoshinari (2004): Damage from the 1945 Mikawa Earthquake, Monthly Earth, vol. 26, No. 12, 825-831.

[6] Takemura Masayuki,Toraya Kenji(2015): Re-evaluation of the regional seismic intensity distribution and damage characteristics of the 1944 Tonankai Earthquake, Transactions of the Japan Society for Earthquake Engineering, Vol. 15, No. 7, p. 7_2-7_21

[7] Anjo City (1971): Anjo City History, pp.1048.

[8] Kanori River Bad Water Ordinary Water Users Association Magazine Compilation Committee (1956): Kanori River Bad Water Regular Water Users Association Magazine, pp.352-356.

[9] Nishio City History Compilation Committee (1973): Nishio City History (Natural Environment, Primitive and Ancient) 1, 602-622.

[10] Aichi Pref.Wure Division (1945): Damage caused by two causes of the air raid on the earthquake, Aichi Prefectural Security Section.

[11] Aichi Prefectural Board of Education (1975): Aichi Prefectural Education History, Vol. 4, pp. 358-655.

[12] Nobuhisa Matta, Fumiaki Kimata (2014): Relationship between fatalities and active faults and topography in the Mikawa Earthquake, Abstracts for the 31st Workshop on Historical Earthquakes (Nagoya Convention)

[13] Nishio City General Affairs Department, Management Section Earthquake Countermeasures Section (1974): Tonankai Earthquake Mikawa Earthquake Experience Collection, pp369.

[14] Committee of "Wasereji" compilation committee (1977): "Wasureji"-Record of the damage of Katahara due to Mikawa earthquake-, Mikawa Earthquake Memorial Project, 11-237.

[15] Haruka Nakai, Masayuki Takemura(2015): Re-Evaluation of Seismic Intensity Distribution from the 1945 Mikawa Earthquake and Its Disaster Characteristics,Vol.15 No.7 Special Issue on the 14th Japan Earthquake Engineering Symposium Part 1 p.7_220-7_229.

[16] Haruka Nakai, Masayuki Takemura (2017): Relationships between the Number of Totally Collapsed Wooden Houses and the Number of Death Tool in the 1945 Mikawa Earthquake, Volume 17, Issue 2 p. 2_23-2_37.

[17] Takafumi Moroi, Masayuki Takemura (2002): Arrangement of Damage Data of Wooden Houses and Estimation of Seismic Intensity Distribution by the Kanto Earthquake (September 1, 1923), Transactions of the Japan Association for Earthquake Engineering, 2 (No. 3), 35- 71.