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**Present Status and Problems on Countermeasures
to Earthquake Disasters
with Emphasis on Disaster-Resistivities
of Cities and their Lifelines**

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**Present Status and Problems on Countermeasures to
Earthquake Disasters with Emphasis on Disaster-
Resistivities of Cities and their Lifelines**

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Preface

In the end of 1974, abrupt changes of ground levels observed in Kawasaki City and its adjacent area along Tama River triggered a controversy on urgent countermeasures to earthquake disasters. Meanwhile mass communications excited to report various opinions of Japanese, U.S. and USSR's scientists on earthquake predictions at the same period. After then an unexpected success in reducing disasters brought by an earthquake occurred in Liaotung Peninsula in the People's Republic of China by employing earthquake predictions was reported dramatically. In the Tongsan earthquake of 1976 the prediction, however lost any success, accordingly it seems that the earthquake brought a mass of death next to the biggest loss in the history of human beings, eight hundred and thirty thousand heads of the Shansi Earthquake occurred in Shansi Province in China 1556.

A while ago, a hypothesis on high potential of earthquake risks in Tokai District proposed by Dr. Ishibashi, Ex-member of Science Department of the University of Tokyo in Spring of 1976, was directly accepted by the Diet, the Cabinet, the academy and the other institutions concerned. Due to the event earthquake measures have looked for the new steps to start with accompanied by earthquake predictions.

Earthquake measures nowadays are roughly divided into " Prediction of Earthquakes " and " Countermeasures for disaster prevention ". In the following, present status and problems concerned are introduced briefly.

1. Countermeasures to Earthquake Disasters

As one knows earthquakes have brought serious and awful problems in Japan, and it is incredible to look on gradually closing and increasing dangers without any trial to find a way out. Among all of natural disasters, especially earthquakes cause the greatest loss of human lives and properties. (refer to Table 1.) In central Japanese land along Pacific coast with relatively high density of population, if there occurs such earthquake of around eight of Magnitude, as the Kanto Earthquake of 1923, it is said that several hundred thousand lives will be lost carrying with a possible loss of some tens trillion yens (\$ two hundred billion) exceeding the budget of Japanese Government.

The countermeasures to earthquakes are aiming at mitigation of losses of human lives and properties caused by earthquakes with a high probability of the occurrence which are naturally immanent in Japanese islands, namely, aiming at the reduction of human damage and economical losses so as to minimize disturbances in activities of both of citizens and enterprises concerning production, circulation and consumption, in activities of administrative agencies and in socio-cultural activities such as educations, cultures, recreation and entertainments.

According to the best of many believes, it is although impossible to completely avoid disasters brought by earthquakes, when central and local governments cope with earthquakes adequately, and citizens and individuals behave as a member of the community properly, it is possible to mitigate almost all of the disasters.

One of targets in the adequate measures of administrative agencies is to get an equilibrium between safety and economy. Entrusted public investments as well as private investments should be efficiently applied under a careful guideline.

However, the phenomena caused by earthquakes are of immense variety even in physical phases. These phenomena should be proved with scientific facts and rearranged as utilizing them for the countermeasures technically and administratively.

On the other hand, many phenomena concerned with economy, sociology and psychology related to earthquakes are not clear to comprehend as much as seashells speak hard about oceans. The opinions concerning them are for the most part, short at objectivity, though they have much of guidance and instruction. And so, there is a question that they should be applied to the counter-measure only after resolving them scientifically.

Here lies a very difficult problem in the promotion of earthquake countermeasures. It would be necessary to place hypotheses for reexamination on facts, to pile up the vague facts one upon another many times for examining facts and falsehood, and to finally refine the hypotheses from more believable images. At the same time, the result of the repetition of such trials should be thoughtfully reflected upon the countermeasures.

Heretofore, in the words "earthquake countermeasures" there has mainly implied at first earthquake proof of structures. But now, the word has been changed to fresh idea consisting of earthquake predictions and improvements of resistivities of districts to earthquakes. The resistivity is going to be recognized as consisting of not only those of earthquake-proof, fire-proof and inundation-proof but also matters concerned with after-earthquake functions of facilities, indicators of local and groval land use planning.

As mentioned above, in addition with earthquake-proof the earthquake countermeasures has become concrete in "earthquake predictions" and in "improvements of resistivities of districts to earthquakes".

2. Predictions of Earthquakes

The writer of the present paper is not originally concerned with the earthquake predictions directly, but is concerned not only with the countermeasures to disasters from earthquakes before the prediction but also with the countermeasures after the prediction and after occurrences of earthquakes, and consequently he must have a deep interest in the earthquake prediction. In the present paper it is intended to show, how the earthquake prediction is gazed at and understood by the writer on such a standpoint.

Around a forecast of earthquake disasters in Kanto district, in the period from the end of Meiji era until early in Taisho era, between two representative seismologists, Prof. Omori and Prof. Imamura, the University of Tokyo, there was a controversy from opposing opinions, as the proverb says : "Two great men cannot exist together". Imamura anticipated that a great earthquake would occur in the off Sagami near Tokyo in the future, and insisted on the necessity of countermeasures to the future earthquake at the capital Tokyo. On the contrary, omori criticized Imamura's coments such as the thought of a great earthquake in Tokyo in the near future was not scientifically based.

In the dispute between Omori and Imamura, there were differences of thier viewpoints about social influence of earthquake predictions. It is said that Omori was anxious of the actual increase of social uneasiness by Imamura's coments, and so he rejected them as a conjection.

In the twelfth year of Taisho (1923) the Kanto Earthquake occurred as to realize Imamura's coments, a great disaster occurred, a hundred and several ten thousand were killed, and the damage of five billion yen in the value at that time occurred. Besides, whether Imamura's coments corresponded to scientific and technological or not, Imamura became the founder of the earthquake prediction study in Japan. Thereafter, for the Tonankaido Earthquake in the nineteenth year of Showa (1944) and for the Nankaido Earthquake in the twenty-first year of Showa (1946), Imamura announced the occurrences of these earthquakes already several years before.

Prof. Imamura believed that the prevention of earthquake disasters should be accomplished with earthquake predictions, and so devoted himself to the research of the prediction almost by himself only, stimulated by his belief many scientists announced their forecasts individually, but the greater part of them failed after World War II, and consequently said that thus the distrust was born in earthquake predictions.

In the thirty-seventh year of Showa (1962) an earthquake prediction study group which was taken jointly care by three scientists, Prof. Tsuboi, Wadachi and Hagiwara, indicated an outline of an earthquake prediction program. This program was commonly called "the blueprint", and was so rough that investments of ten billion yen budget for ten years would bring conclusions whether the earthquake prediction is scientifically possible or not.

Afterwards, through many negotiations and procedures in the fortieth fiscal year of Showa (1965), the amount of 175 million yen was provided as the budget related to the program and in the fifty-first fiscal year (1976) the amount was rapidly elevated to 2313 million yen. Furthermore, the organizations and thier systems of promotion of earthquake predictions are as shown in Figure 1, which can not be easily understood at a glance. This system is although supposed neither to be serviceable nor to be perfect, a part of them which has become a concrete duty such as the Task Force of Judgement for Tokai District may be evaluated.

The earthquake predictions nowadays are employing many methods, for example, topographical survey for observation of horizontal strain of the ground, level survey for observation of upheavals and subsidenses, changes in velocities of seismic waves, changes in electromagnetic properties of rocks, and changes in underground water and so on. Accordingly, the prediction can be realized by employing the synthetic judgement of much observed information providing from existing various organizations. In this situation it is indispensable that the system consists of research institutions and organizations of services complicatedly.

In the long-term view, on the phase of the policy of the disaster prevention, it will be meaningful to recommend founding such a new agency as the Earthquake Agency of the People's Republic of China, in order to promote the unification of prediction services, and also to efficiently promote disaster prevention services by cutting off institutions concerned with pure science in this system.

Nowadays, as Prof. Imamura believed, without the prediction the prevention cannot be considered. The prediction service due to accumulating many experiences, should establish its pertinent system, and produce its own efficient procedures in the future.

3. Disaster Resistivities of Urban Districts

As mentioned above, the earthquake countermeasures hitherto were promoted with emphasis upon the earthquake-proof of structures. However, the disasters of houses in the Kanto Earthquake of 1923 were as follows,

Burnt	447,128 houses
Razed	128,266 houses
Half Razed	126,231 houses
Lost by Floods	868 houses

As seen from above, the damage by fire is much greater than that by shaking. Though the former does not occur so instantaneously as the latter does, in case of the Kanto Earthquake, fires occurred in many places at the same time and the damage was spreaded and expanded. As the result, very many lives were lost in addition to substantial damage.

On the contrary, in the Tottori Earthquake of 1943 and the Fukui Earthquake of 1948, the disasters by shaking widely surpassed those by fire as shown belows,

	Tottori Earthquake	Fukui Earthquake
Burnt	254 houses	3,960 houses
Razed	7,485 houses	35,420 houses
Half Razed	6,158 houses	11,449 houses
Lost by Floods	none	none

These historical facts indicate that the damage by fire is prevailing in larger cities, and those by shaking in local cities. Furthermore, in case of our country, there are disasters caused by water, namely, by tsunamis in coastal regions and by inundations in lowlands along sea coasts and rivers. As one of the other factors which further increase these physical disasters and the loss of human lives, the panic may be considered.

These disasters are consisting of direct losses from earthquakes, but as the indirect losses which occurs after earthquakes, we may consider economical confusion, collapse of local societies or communities, and changes of international relations.

Prof. Toshihiko Kato (Sociological Science Institute, the University of Tokyo) has analyzed from financial and monetary aspects, "that the disaster of the Kanto Earthquake occurred under a way to depression after a boom of economy during World War I which had been tranquilized. Due to the earthquake the depression was accelerated, the economy of our country was brought ruin, and in consequence it fell into the advance into Manchuria, the invasion into China, and finally into World War II".

If a disastrous earthquake occurs as covering with whole areas such the Metropolitan area where all sorts of functions are densely packed, the influence of the earthquake are immeasurably large. Accordingly, causative factors as to be triggers for damage by shaking, fires, floods and panics, must be investigated, and in order to cut off the disaster in its primary stage, the factors of disaster expansion should be removed.

Durableness of a city to disasters, or rare occurrence of disasters of a city, is called "disaster resistivity of cities". Namely, this is a concept which is defined by assuming those of earthquake disasters, floods and great fires resulting only from natural effects such as earthquakes, typhoons and strong winds except such avoidable disasters as epidemics and wars.

Well, let us temporarily name the disaster-resistivity of a city to earthquakes as the earthquake disaster-resistivity, and let us go ahead.

As for the scale to measure the seismic disaster-resistivity, there has not yet been any such scales so clear as design seismic coefficients in earthquake-resistant design. However, the several elements shown below may be considered in defining such scales.

◦ Geographical and natural elements:

Density of population and its distribution ----- (Depopulation and concentration)

Sorts of industries and their distribution ----- (Density of industrial distribution)

Vacant lands and aquatic area ----- (Open spaces)

Topography and altitudes ----- (Landslide, inundation)

Meteorological and hydrological phenomena ----- (wind, flood)

° Physical and artificial elements:

Frequencies of earthquakes and intensities of ground motions --
--- (Intensities of earthquakes)

Geology and soil properties ----- (ground conditions)

Aseismic resistances and fire-resitant properties -----
(Properties of structures)

Water supply and energy supply ----- (Water, gas, electricity,
and petroleum)

° Dynamic and planning elements:

Population in day and night ----- (Short-term movement of
population)

Dangerous facilities and disaster-prevention facilities -----
(Potentials of disaster occurrence in facilities)

Flow of goods and traffic volume ----- (Activities of dis-
tricts)

Regional planning and urban planning ----- (Redevelopments
of cities)

° Social and cultural elements:

Origination and transmission of information ----- (Networks
of information)

Control functions and local functions ----- (Administrations)

Cultural inheritances and convenience facilities -----
(Historical changes)

Divisions of elements and their contents in all of the aboves
are not necessarily adequate, and the other items may be added.
From this, it is insufficient to clearly measure the earthquake
disaster-resistivity in our knowledge.

In contrast to the earthquake disaster-resistivity, an idea of earthquake disaster risk potentials exists. Tokyo Metropolitan Government made trials for this idea, and the results obtained in the 49th fiscal year of Showa (1974) have found, for each of the items shown below, the relative risk potentials among twenty three of the wards.

- i. Accumulated risk potentials for wooden buildings
(earthquake-resistances of grounds and buildings)
- ii. Risk potentials due to local characteristics
(population, open spaces and traffic volume)
- iii. Accumulated fire risk potentials (outbreaks of fires)
- iv. Risk potentials due to burnt houses (by spreading fires)
for the two cases of fire fighting powers included or not
- v. Risk potentials from refuge distances (refuge distances)

These relative risk potentials classified by items as above are totally piled up, and the totalized risk potentials are finally obtained. The order of 5 wards having higher potentials is as follows,

	(Fire fighting powers included)	(Fire fighting powers not included)
1st	Sumida	Sumida
2nd	Arakawa	Arakawa
3rd	Taitō	Taitō
4th	Toshima	Toshima
5th	Kōtō	Shinagawa

The order of 5 wards having the lower potentials from the lowest is as follows,

	(Fire fighting powers included)	(Fire fighting powers not included)
1st	Minato	Minato
2nd	Bunkyo	Nerima
3rd	Nerima	Setagaya
4th	Chūō	Chiyoda
5th	Setagaya	Chūō

In the above-mentioned 'earthquake disaster risk potentials' of Tokyo, the public works or facilities other than roads, parks and green zones were not included in the evaluation. However, all of urban public works are so-called lifeline systems in earthquake engineering and they are indispensable to evaluate earthquake disaster risk potentials, but all of them were not included in the evaluation of Tokyo. And disasters by water during and after earthquakes were not included in the evaluation either.

It is easy to find out some items lacking in the evaluation done, but there are many difficulties to obtain a totalized evaluation satisfying all of the important elements.

"A guide-line for drafting programs on mitigation of earthquake disasters in three major metropolitan areas, Tokyo, Nagoya and Ōsaka (draft)" issued by Ministry of Construction in August 1975 gives such a direction for the existing urban area and their suburban areas, as the scale and density on installation of facilities serving for safety.

This guide-line is, so to speak, a tentative guide-line which, by making a new step of advance from being a merely qualitative indicator showing the potentiality of earthquake risks, aims improvements of urban disaster-resistivities and protections of human lives.

The guide-line (draft) is composed as follows,

- i. Object areas.
- ii. Extensive refuge places.
- iii. Allocations of extensive refuge places and refuge roads.
- iv. Refuge roads.
- v. Buffer zones.
- vi. Water-gates, channels and pumping stations to inundations.
- vii. Strategy for arrangement and promotion.
- viii. Others.

This composition suggests that urban disaster-resistivities at present will be greatly improved by aiming primarily at the safety of human lives and next at the prevention of enlargements of disasters.

4. Distribution of Earthquake Damage to Wooden Houses

(1) Evaluation of distribution of earthquake damage by shaking

How is the earthquake damage distributed? The distribution of the earthquake damage in the Fukui Earthquake of 1948 is shown in Fig. 2. The circles in the figure indicate places where ground conditions are relatively sound, and the black spots indicate places where the ground is not sound and they are suffered from the earthquake damage in the ratio larger than 1%.

Fukui Earthquake of 1948 ($M = 7.3$, $H = 20$ km)

Izu Peninsula Earthquake of 1974 ($M = 6.8$, $H = 20$ km)

Ebino Earthquake of 1968 ($M = 6.1$, $H = 0$ km)

In the medium-scale earthquakes above with Magnitude of 6.1 through 7.3 and depths of hypocenters, H of 20 km or less, the distributions of ratios of the earthquake damage to wooden houses were statistically analyzed as follows,

$$D_{II} = \frac{1}{164} \times 10^{(0.625M + 0.025M \cdot \Delta - 0.272)}, \text{ ---- (1)}$$

$$D_{II} = \frac{1}{73} \times 10^{(0.576M + 0.026M \cdot \Delta - 0.248)}, \text{ ---- (2)}$$

where

D_{II} : ratios of earthquake damage to wooden houses (in %) in relatively sound ground conditions (I region),

D_{II} : ratios of earthquake damage to wooden houses (in %) in bad ground condition (II region).

$$\text{The earthquake damage ratios} = \frac{\text{Number of razed houses} + 0.5}{\text{Total number of existing houses}} \times 100, \text{ in \%}$$

M : Magnitude of earthquakes

Δ : epicentral distances (in km)

Research on the distribution of the earthquake damage ratios has already been done by Professors Omote, Minakami, Uchibori, and all of these researches employ the functions of the ratio as being proportional to exponentials of epicentral distances. In the above equations (1) and (2) the Magnitude and ground conditions were taken account into consideration. Ground condition I region means the layers of diluvium and Tertiary, ground condition II region for the alluvium layers.

As clearly seen from the equations, in I region the earthquake damage ratio is smaller than in II region. Larger Magnitude brings larger earthquake damage ratios and larger epicentral distances bring smaller earthquake damage ratios. These relationships are illustrated in Figure 3.

Then, in the application of the relationships to actual earthquakes, comprehensive evaluations would be possible or not. As a trial, taking the Ansei-Edo Earthquake of 1855 as a sample, the epicenter was located at the northern part of Tokyo at a location of N 35.8° and E 139.8° .

In Equations (1) and (2) structural characteristics of wooden houses i.e. one story or two story and also the effects of thickness of alluvium layer were not taken account. Therefore, by employing some results of researches upon them, the ratio from Equations (1) and (2) was corrected in this trial. In each ward of Tokyo, the earthquake damage ratios corresponding to 6.0, 6.5, 7.0 of Magnitudes were obtained as shown in Fig. 4.

In this figure great earthquake damage ratios are shown in the four wards of Adachi, Katsushika, Kita and Arakawa near the epicenter and also the wards of Sumida, Taitō and Kōtō located in delta.

In Figure 5. the analytical distribution of the earthquake damage ratios for the Ansei Edo Earthquake was shown with the present in wards of Tokyo. The structural characteristics of houses 200 years ago might be though different than at the present, temporarily using the characteristics at the present because of a lack of the data, and

assuming the thickness of Alluvium layers as same as the present one, the earthquake damage ratios of every ward in the area of the central part of Tokyo were analyzed and they are compared with the actual ratios occurred in Table 2.

The three wards occupying upper ranks of the analyzed ratios are included in the upper five wards of the earthquake disaster risk potentials obtained by Tokyo metropolitan government dealt with fire damage risks. And the lowest two wards of the analyzed ratios do not coincide with the actual phenomena both qualitatively and quantitatively. It seems that there immanently are some extraordinary causes, but they have not been yet clarified at present.

(2) Fire damage in earthquakes

From the approximate coincidence of the wards of Tokyo occupying higher ranks of the earthquake disaster risk potential for mainly fire damage by the investigation of Tokyo Metropolitan government with the wards occupying higher ranks of the earthquake damage ratios, it is indicated that between the earthquake damage ratio and the fire damage of earthquakes there may be some correlations. However, in case of the Fukui Earthquake of 1948 the similarity between the number of burnt houses by fires and damage by shaking cannot be observed. (See Fig. 6)

Damage by fires in earthquakes is affected by the possibility of outbreaks of fires, the possibility of expanding of fires, the meteorological conditions, and the fire fighting powers. In macroscopic points of view, however, an equation of the evaluation was obtained by Prof. Kawazumi as follows,

$$B = 10^{-5} \times N^2, \text{ ----- (3)}$$

where B : number of burnt houses,

N : number of razed houses,

$$\text{and } N = 0.2 \times 10^{2(M-5)},$$

where M : earthquake magnitude.

In Equation (3), it is known that about one house is burnt down at $M = 6.5$. However, at $M = 8.0$ a million houses are burnt down. The fact that 450 thousand houses were burnt down in the Kanto Earthquake with $M = 7.9$ surely supports Prof. Kawazumi's equation.

At the present the evaluation of the distribution of fire damage in earthquakes may be not easy owing to many conditions.

It rather is necessary to make efforts for the development to decrease the fire sources and to reform houses as hardly inflammable even in the case of outbreaks of fire.

5. Importance Factors and Disaster-Resistivities of Lifeline Systems in Earthquakes

(1) Lifeline systems

In 1971, the San Fernando Earthquake which occurred in the suburbs of Los Angeles brought great damage in roads and other public facilities, and after then the word "lifeline" has been used in wider sense.

Relations between various facilities and governmental agencies in charge in Japan are shown in Table 3. From this table, many facilities related to lifelines are selected and, with some supplements, listed in the following,

Facilities	Elements
Transportation	Road, street, railway, airport and harbour
Communication	Telegram, telephone, mail, broadcasting and newspaper
Sanitary	Watersupply, sewerage and solid waste disposal
Energy	Electricity, gas and liquid fuel
Vacant area	River, lake park, greenzone and open space

All of them are indeed the indispensable facilities in and after earthquakes occurred in large cities. Gases and liquid fuels are needed as heat sources, but on the other hand, they have the possibility of increasing expansion of fires. In addition, the facility of vacant areas is one of the lifelines, which should be seriously considered in Japan with densely populated characteristics in many cities located in one of the strongest earthquake regions in the world.

In the United States of America the word "Lifeline earthquake engineering" is prevailing among the civil engineers, and the contents of the word are in considerable parts, coincident with those of the so-called "earthquake engineering concerned with public works or facilities" in Japan.

(2) The importance factors of lifelines.

A picture of an armored knight in the Middle Ages, proceeding to battlefields, followed by soldiers, somehow resembles the present

state of the earthquake countermeasures of lifelines. It is imagined that, in the battlefield which is rarely scattered with such a knight in arrow-resistant armors, a group of his soldiers, each of them having a shield as his protector and holding a spear ready to attack, rushes in a body towards the enemy.

It seems that some resemblance exists between the protection against natural hazards such as earthquakes and tactics on battlefields. Facilities which are generally named "lifelines" have respectively their individual characteristics, and probably should be ranked according to their importance in emergency.

In this consideration the strong-armored facilities with large functional capacities should be installed in important strategic points and fronts.

Accordingly, such as various adequate responses in case of battles, e.g. alternations of soldiers, guarantee of commissary, communications, first aid, withdrawal in the worst case, etc., those are similar ideas of the improvement and arrangement of lifelines for an emergency. Almost all of public facilities are included in the important facilities which should be retrofitted, and in fact, at present the retrofitting is advanced more than others.

However energy must be supplied from its sources into cities, as well as bullets must be carried into battle fields. After it catches once fire in such gas and liquid fuel as the energy sources they would make fire very expanded and resulting the functions of the important facilities, as mentioned above could be lost.

According to an extracted census mainly conducted to an object of technological specialists, the opinion of the majority of all indicates that the importance factors of the important facilities should be taken larger than others for strengthening and refining them to effects of earthquakes in earthquake resistant design. But as for the influence of dangerous substances to the important facilities the opinions are divided into two, namely, one which stated that the facilities containing dangerous substances should protect the dangerous

influence to other facilities by themselves and another one which stated that all of the important facilities should be more strongly armored.

In the important facilities of public works, through the period of economical recovery a while after World War II, it has been commenced to make them more earthquake-resistant and noninflammable with emphasis on the quality, but in the industrial facilities and residential houses, the investments have developed with emphasis on the quantity than the quality. On the safety of the city it must be anxious such situation as they are developed too congested and mixed in large cities.

Now, concerning the problem of the lifelines with high importance, there regrettably no clear standard to treat concretely. But if we must say forcibly, the following four items may be indicated.

- i. The facilities must have marginal functional-capacities.
- ii. The facilities must have a dummy to substitute the function.
- iii. The facilities must have a measure to promptly recover the functions immediately after the disaster.
- iv. The facilities must have an uniformity in the functional and structural capacities among them.

It will be clear that the disaster-resistivity of the lifelines in earthquakes is much improved by these measures.

(3) The residual life and disaster-resistivity of lifeline systems

Though it is an ideal situation that the simple and clear measures as stated above could be taken for improvement of the disaster-resistivity in earthquakes, corresponding to actually ordinary and daily demands the problem is usually arranged by considering growth of utilization for future demands and effects of investments etc.

It is really meaningless to require applications of safety measures at once, which are much superior than gross national economy. In the matters concerning the improvement of the disaster-resistivity of the lifelines, it is hardly realizable to pursue an ideal situation only,

and it does not create any progress to make compromise with reality always. There is a question to reduce some gaps between ideal and real situations in considerations.

Here, a consideration will be presented about the improvement of the disaster-resistivity of lifelines by employing their residual lives. The residual life is the length of time obtained by the subtraction of ready-served times from durable life-times of structures. Now, in the following there is shown an example of bridges in case of Kanto district for consideration of their earthquake-resistance.

Assumptions are as follows,

- i. Probability of earthquake damage (U^*), namely, the probability of earthquake damage (complete losses of the functions) of bridges which have existed since the Kanto Earthquake of 1923, is assumed to be 2.1×10^{-3} .
(The probability of human earthquake damage (death) is supposed to be $10^{-3} \sim 10^{-4}$ for reference.)
- ii. Capacities of earthquake resistances of bridges (R) is exponential-functionally degrading depending time passing.
- iii. Durable life-time of bridges are assumed at 50 years.

Examples of the analyses are shown in Figure 7 and 8.

Meanings of symbol in the figures are as follows,

- R_0 : Required capacities of earthquake resistance of bridges
- ΔR : Retrofitting ratios between capacities retrofitted and required.
- Curve A : Changes of the existing capacity without any retrofitting
- Curve B : Changes of the retrofitted capacity to maintain the level of required capacities corresponding to the durable life of 50 years at any moment.
- Curve C : Changes of the retrofitted capacity to maintain the level of the required capacities corresponding to the residual life at any moment, but with reductions of probabilities of risks being proportional to ratios of the residual life-time and durable life-time.

In Fig. 7 retrofitting ratios ($\Delta R : B-A$ and $\Delta R' : C-A$) are shown in case of satisfying initially 96 percents of the required capacity. In Fig. 8 retrofitting ratios (ΔR and $\Delta R'$) are shown in case of satisfying the full required capacity, but with reductions of probabilities of risks (1.05×10^{-3}) to half of the assumed probability before.

Some of technological specialists may though reject statistics and probabilities, and perhaps rely on thier intuitions and experiences only, the writer believes that such statistics and probabilities would be recognized to be utilizable as a foundation of logical compositions for finding logics of compromise.

Now, it is not easy to find the principle for improvements and arrangements to earthquakes occurred in cities and lifeline systems in them, with a naive logic. Capacities of the lifeline systems in strengths and functions are limited, and they could not avoid from disastrous damage with a certain probability during periods in even their life-time, and the probability is told by the history. From such situations we must find out the facts of disasters and apply them into.

Conclusions

It is not easy to reform cities safe to earthquakes. During earthquakes, other than abrupt violence of the nature, distorsions and confusions occur in the societies and organizations in cities.

Existing cities have been built without any consideration such distorsions and confusions. According to the statistics, in Tokaidō belt along Pacific coast there live the people of 40% of Japanese population, and produce 80% of gross national products. In short, in these coastal areas there is formed a great colony unprecedented in the history of mankind.

The differences between the ideal images upon the original colony in the ancient days and the real site conditions of the present days would be decreased or increased anyhow. This may be one of the problems to be solved by us hereafter.

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Table 1 Historical Record of the Death by Natural Disasters
In the World

Disasters	Year of Christian Era	Country	Number of Death
Earthquake	1556	China	830,000
Flood and Tidal wave	1642	China (Break on coastal embankment)	300,000
Storm	1876	India	200,000
Volcanic eruption	1693	Italy	60,000
Fire	1871	U.S.A. (Wood fire)	1,152

Table 2 The Ratios of Houses Damaged by the Ansei-Edo
Earthquake of 1855

ratio of houses damaged by earthquake place name	Evaluated ratios*	Observed ratio
(1) Sumida-ward	100 % or more	80 %
(2) Kōtō	84 %	76 %
(3) Taitō	54 %	51 %
(4) Bunkyo	46 %	68 %
(5) Chiyoda	35 %	46 %
(6) Minato	34 %	80 %
(7) Chūō	26 %	8 %

(note) * As to the structural characteristics of houses and the thickness of Alluvium layers in subgrounds, those of the present days are used.

Table 3 Facilities corresponding to Ministries or Agencies in Charge

Ministries or Agencies in charge		prime Minister's Office	M. of Justice	M. of Finance	M. of Education	M. of Health and Welfare	M. of Agriculture and Forestry	M. of International trade and Industry	M. of Transport	M. of Posts and Telecommunications	M. of Construction
Cultural and educational	School				0						
	Physical training				0						
	Social and educational				0						
	Cultural assets				0						
Health and Welfare	Water supply					0					
	Medical service					0					
	Social welfare					0					
	Environmental and sanitary					0					
Agriculture and Forestry	Farmland						0				
	Agricultural						0				
	Woodland path						0				
	Fishery						0				
	Cultivation						0				
Commercial and Industrial	Service and distribution							0			
	Light industries							0			
	Heavy industries							0			
	Mining and raw material manufactures							0			
	Energy							0			
Transport	Railroad								0		
	Land transport								0		
	Marine transport								0		
	Airport								0		
Communication	Telegraph and telephone									0	
	Mail									0	
	Broadcasting									0	
Urban	Sewerage										0
	Street and park										0
Public engineering works	Road										0
	Road-re-lated										0
	River										0
	River-re-lated										0
	Coastal										0
	Sabo										0
House	Individuals' housing										0
	Public housing										0
	Others	Self-Defence Forces of Japan	Criminal affairs	Government employees' housing etc.							

Fig-1 Organization of Earthquake Predictions
(Prepared mainly by Yutaka Sato)

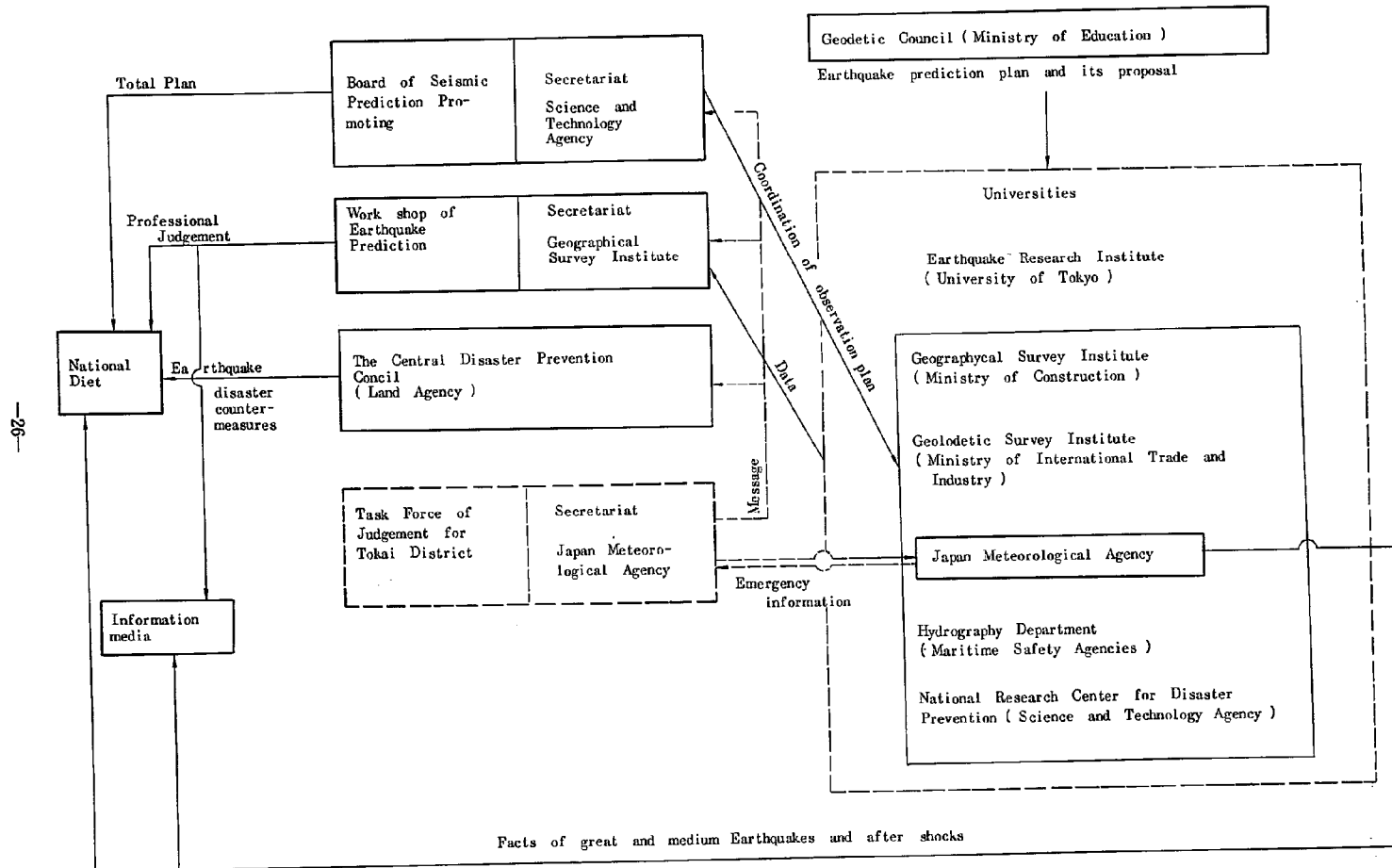
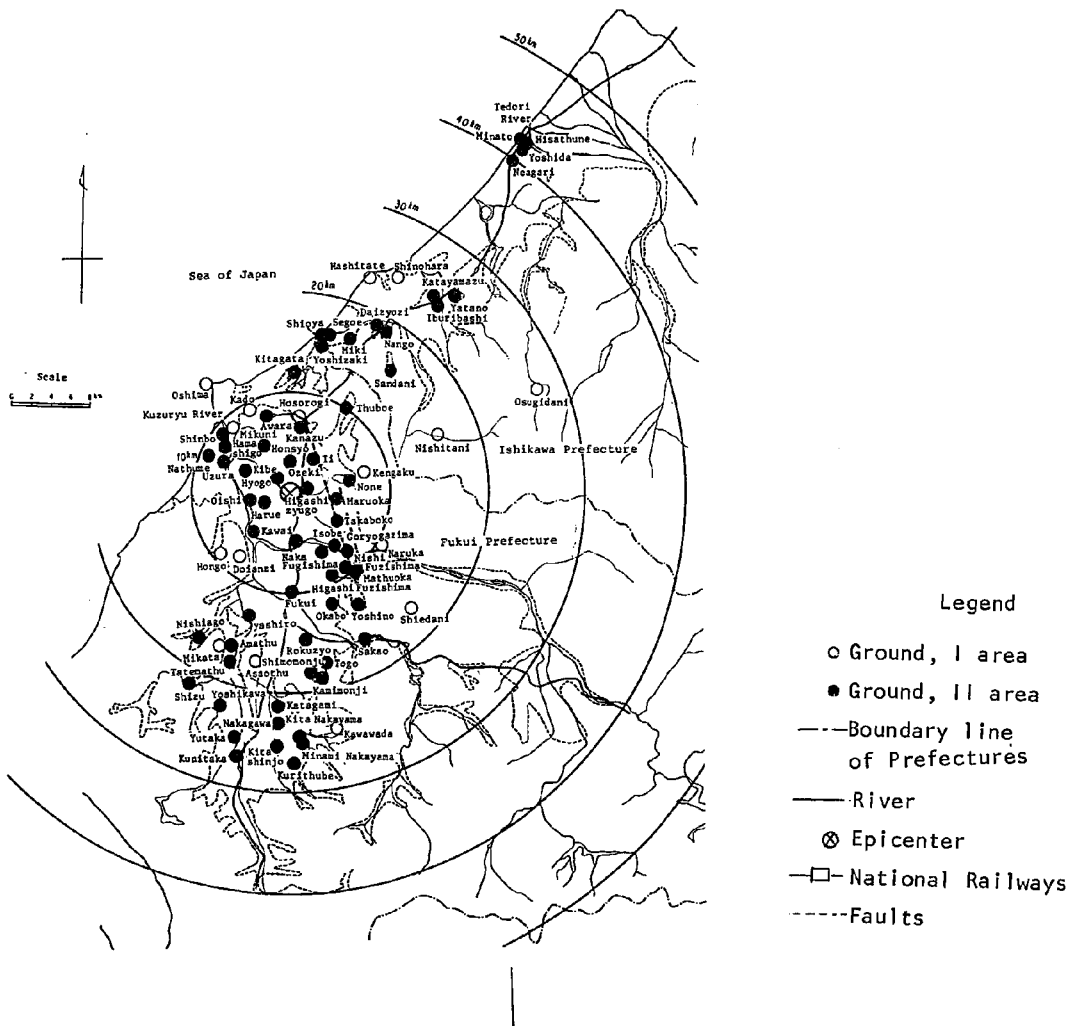


Fig-2 Distribution Maps of towns and villages damaged by the Fukui Earthquake (with the ratio of damaged houses of 1 % and over), classified by the nature of the ground.



(note) As to the faults, their curves are drawn according to the report of Mr. Yoshikatsu Ogasawara (1949): "On the Damage by the Fukui Earthquake and the changes in the ground, especially on the earthquake and the fault movement", Geodetic Survey Institute Review, Special Issue 2.

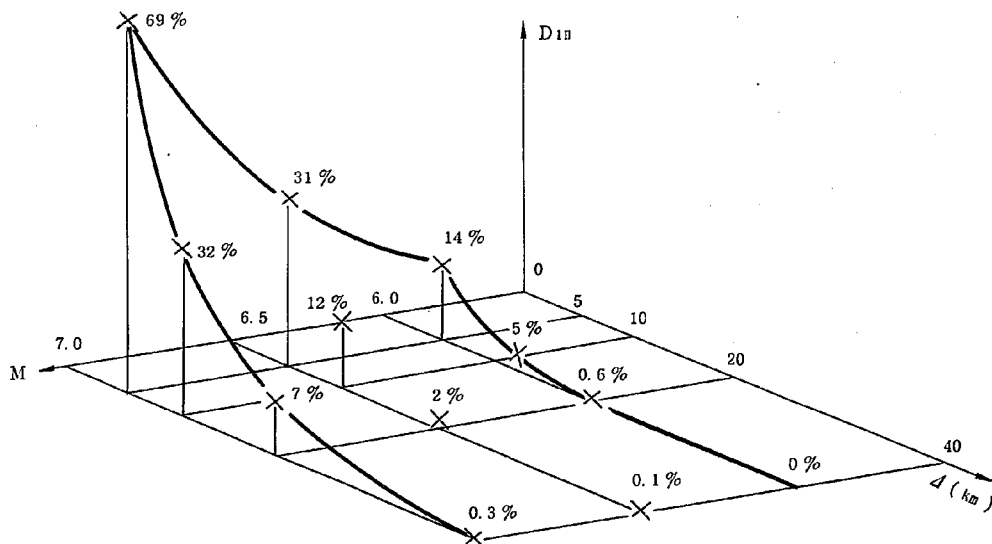
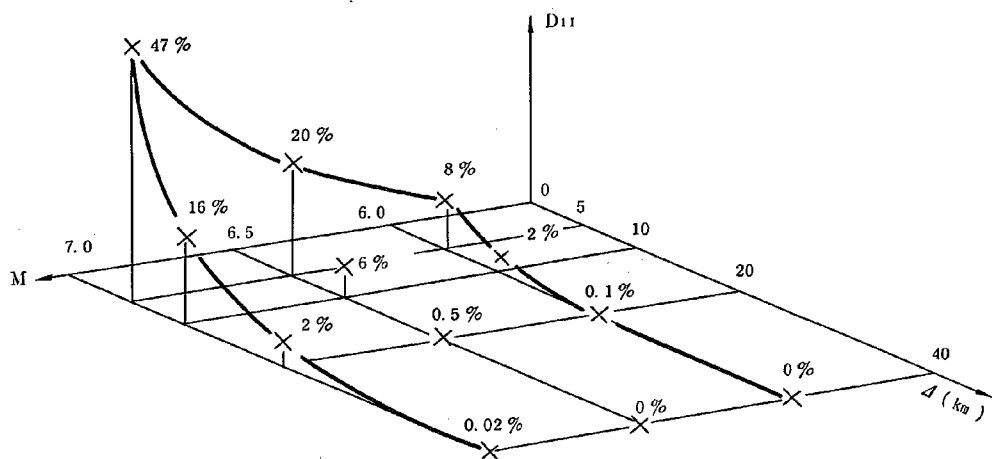


Fig-3 Distributions of the ratios of houses damaged by earthquakes

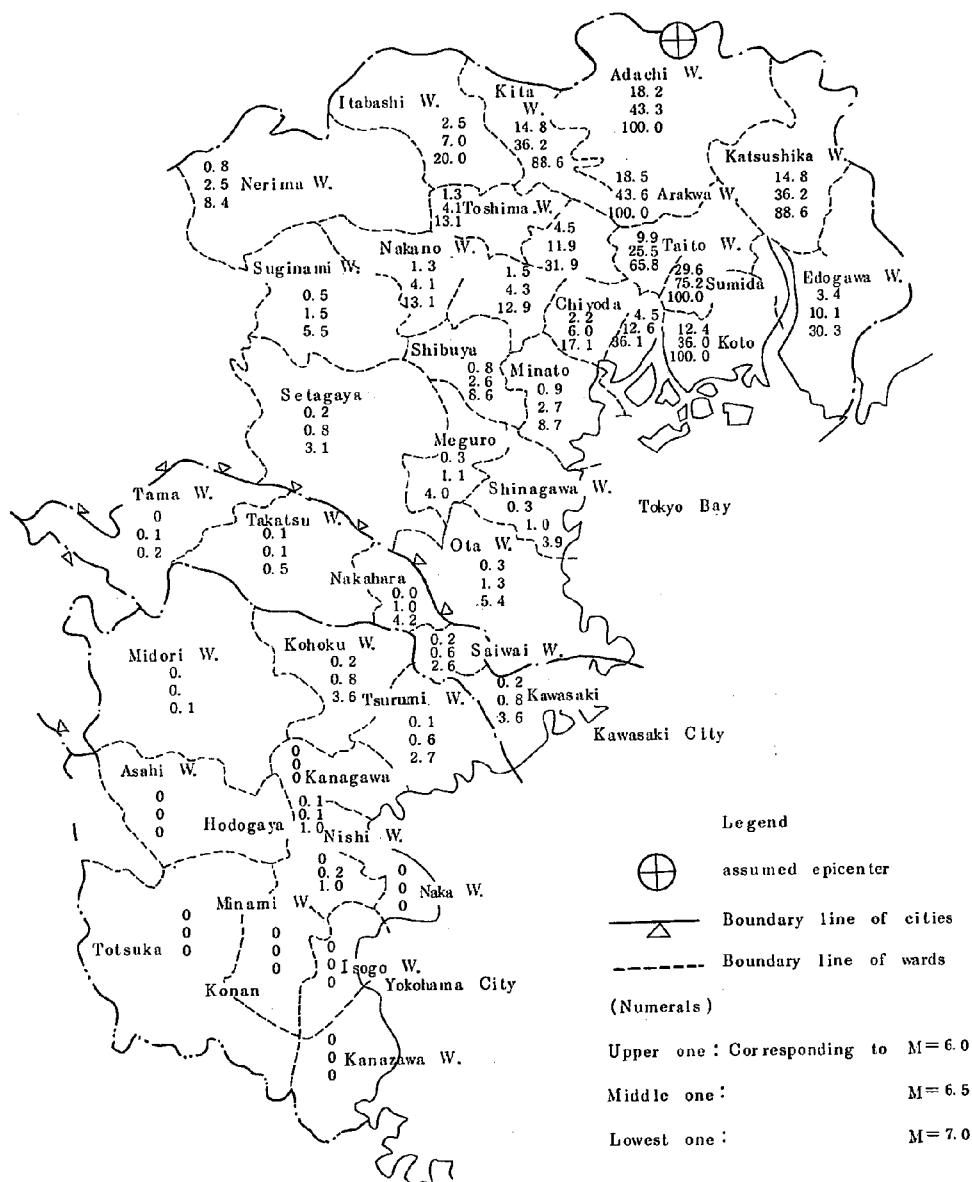


Fig-4 Distributions of the ratios of houses damaged by hypothetical earthquakes $M=6$, 6.5 and 7 , classified by urban wards of Tokyo, Kawasaki and Yokohama

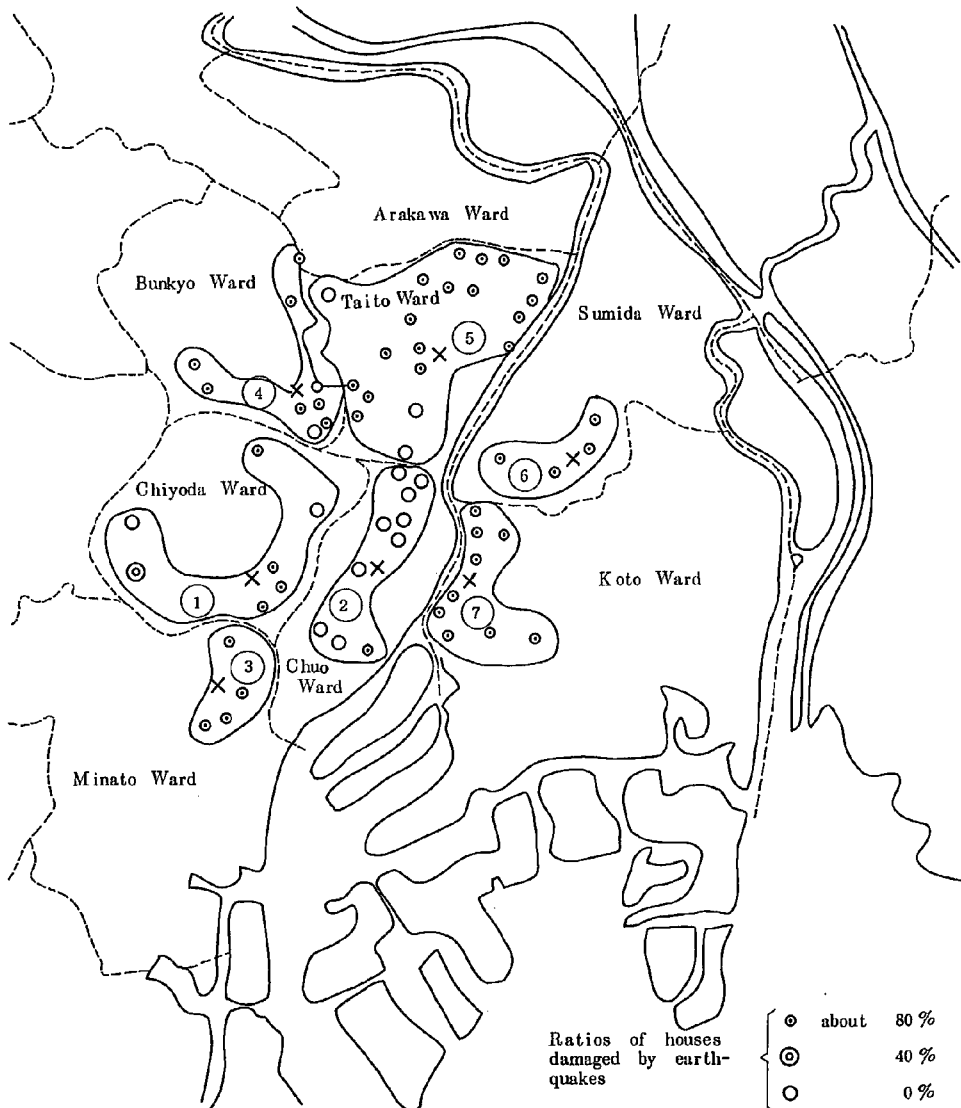


Fig-5 Distributions of the ratios observed of houses damaged by the Ansei-Edo Earthquake of 1855

△ The city, town and village where the ratios of burnt-down houses are more than 1%
 () The ratios of the burst-down houses

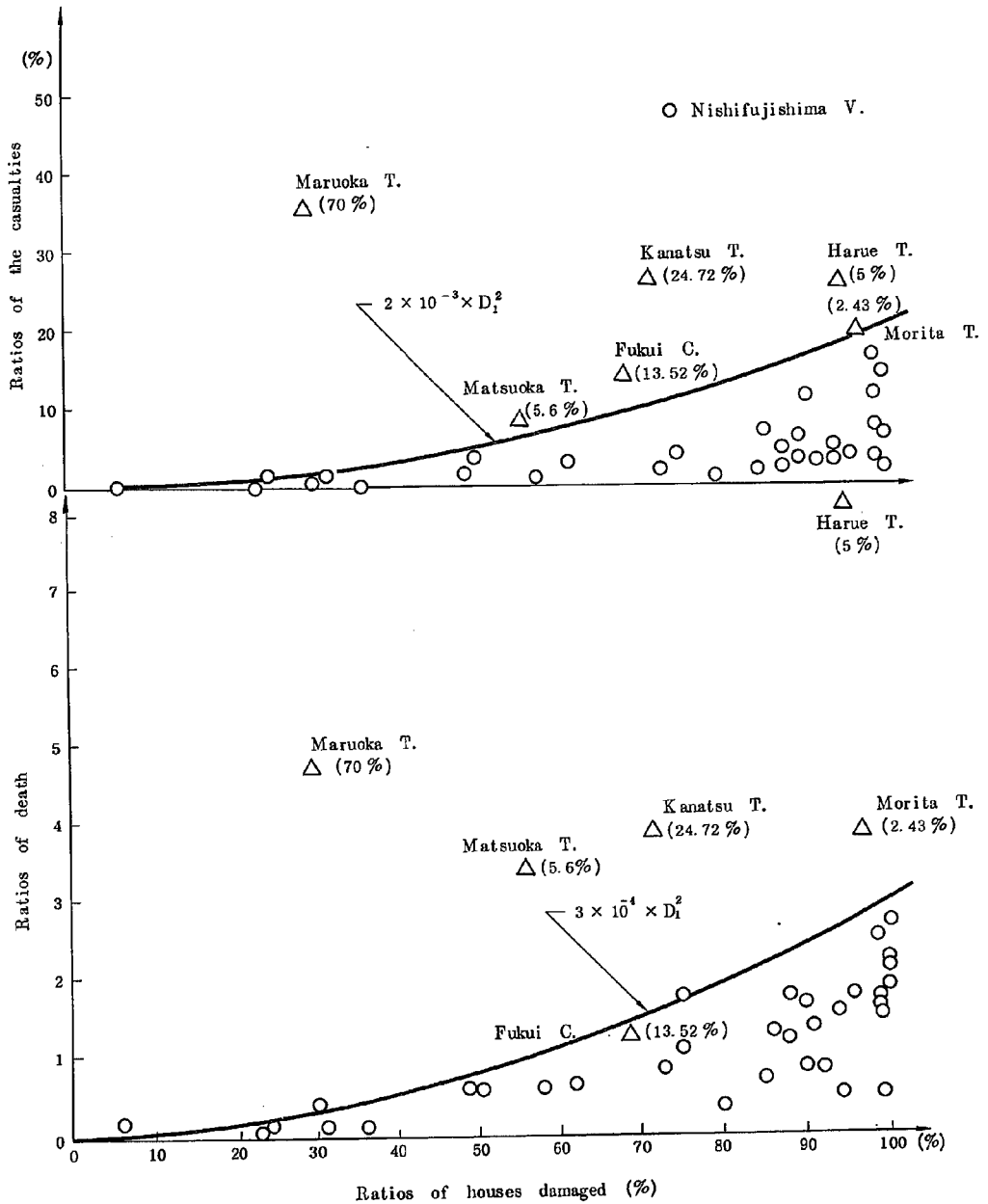


Fig-6 Relations among death, casualty, fire and shaking damage in the Fukui Earthquake of 1948

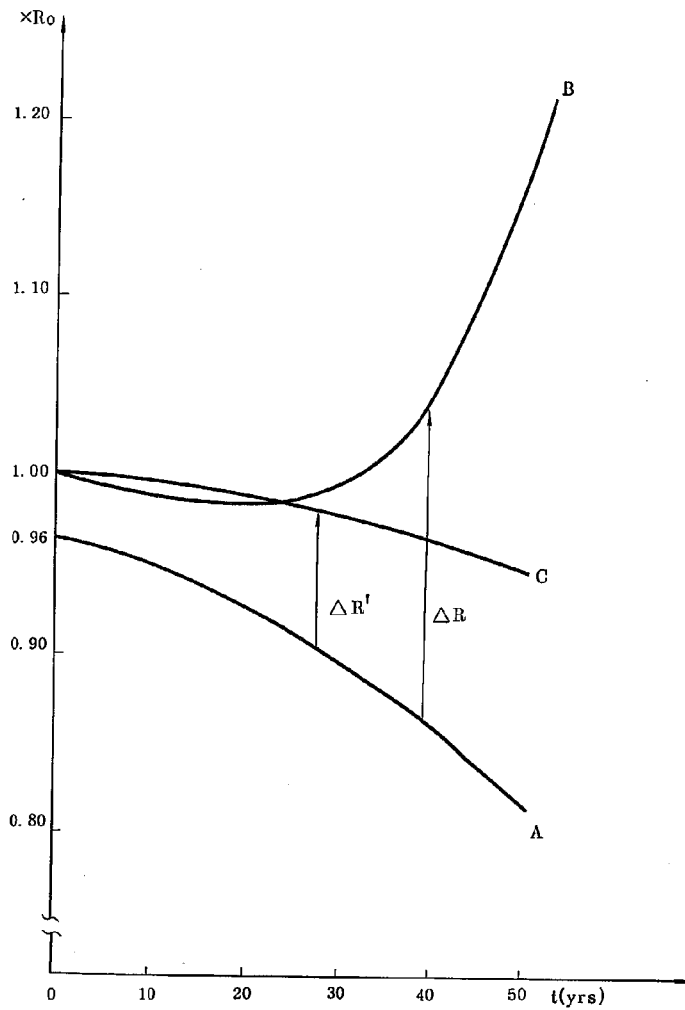


Fig-7 Retrofitting required, case 1

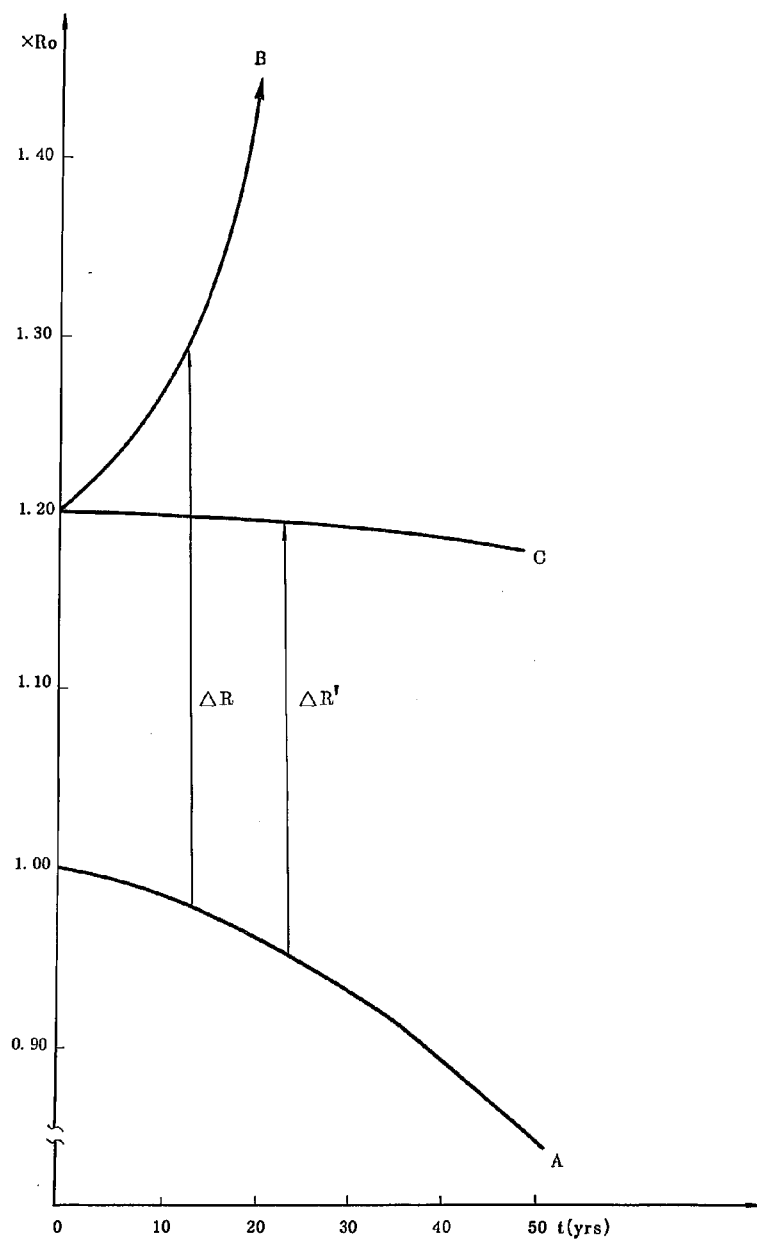


Fig-8 Retrofitting required, case 2