EARTHQUAKE DISASTERS AND DISASTER-RESISTIVITIES

by

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ABSTRACT

The countermeasures to earthquakes are aiming at mitigation of losses of human lives and properties caused by earthquakes with a high probability of the occurence which are naturally immanent in Japanese islands.

Nowadays, earthquake disaster mitigation measures are roughly divided into "Prediction of Earthquakes" and "Countermeasures for Disaster Prevention".

In the following, introduced are present problems concerned to countermeasures, some considerable factors in measuring the earthquake disaster resistivity of cities and a consideration about the improvement of the disaster-resistivity of lifelines.

COUNTERMEASURES TO EARTHQUAKE DISASTERS

Among all of natural disasters, especially earthquakes cause the greatest loss of human lives and properties. (refer Table 1.)

Table 1 Histrical 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

In central Japanese land along Pacific coast with relatively high density of population, if there occures such earthquake of around eight of Magnitude, as the Kanto Earthquake of 1923, it is said that several hundred thousand lives will be lost carring with a possible loss of some tens trillion yens ($ two hundred billion) exceeding the budget of Japanese Government.

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The countermeasures to earthquakes are 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.

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, there is a question that they should be applied to the countermeasure only after resolving them scientifically, though many phenomena concerned with economy, sociology and psychology related to earthquakes are not clear to comprehend.

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 advanced 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.

DISASTER RESISTIVITIES OF URBAN DISTRICTS

As mentioned aboves, 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 (M7.9) were as follows, (1).

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

As seen from aboves, the damage by fire is much greater than that by shaking, and 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 below, (1).

	Tottori Earthquake (M=7.4)	Fukui Earthquake (M=7.3)
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.

In addition to these direct losses, we may consider the indirect losses which occur after earthquakes such as economical confusion, collapse of local societies or communities, and changes of international relations.

If a disastrous earthquake occurs as covering with whole areas such the Metropolitan area where all sorts of functions are densely packed, the influences 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.

As for the scale to measure the erathquake 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 topographical 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-resistant 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 districts)

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 1974 fiscal year have found, for each of the items shown below, the relative risk potentials among twenty three of the wards. (2)

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 aboves 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

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. (3) The guide-line 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.

IMPORTANCE FACTORS AND DISASTER-RESISTIVITIES OF LIFELINE SYSTEMS IN EARTHQUAKES

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. In Japan facilities related to lifelines are selected as follows,

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, seashore, lake, park, green zone 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 worlds.

The importance factors of lifelines

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 infact, 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 so much expanded that 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 majority of the opinions 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. (4)

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

- i. The facilities must have surplus functional-capacities.
- ii. The facilities must have a alternative 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.

The residual life and disaster-resistivity of lifeline systems

Though it is an ideal situation that the simple and clear measures as stated aboves 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.

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 as 50 years.

Examples of the analyses are shown in Figure 1 and 2.

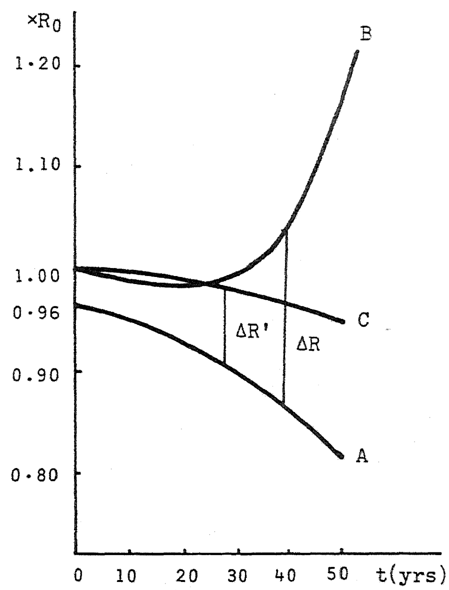

Fig. 1 Retrofitting required,case 1

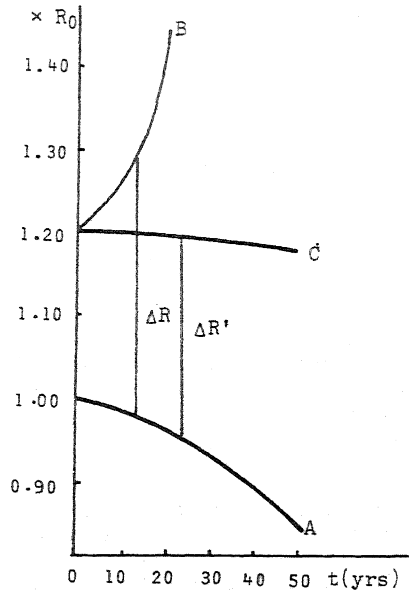

Fig. 2 Retrofitting required,case 2

R_o : 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 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. 1 retrofitting ratios (ΔR : A–B and $\Delta R'$: C–A) are shown in case of satisfying initially 96 percents of the required capacity. In Fig.

2 retrofitting ratios (ΔR and $\Delta R'$) are shown in case of satisying the full required capacity, but with reductions of probabilities of risks (1.05×10^{-3}) to half of the assumed probability before. (5)

CONCLUSIONS

During earthquakes, other than abrupt violence of the nature, distorsions and confusions occur in the societies and organizations in cities, which have been built without any consideration such situations.

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 situation we must find out the facts of disasters and apply them into.

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