BASIC STUDIES ON EARTHQUAKE DISASTER PREVENTION

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Abstract Damage analysis of wooden houses based on seismogeomorphological studies and estimation of the dead and the injured due to great earthquake in future are briefly introduced. Regional danger degree and successive events following earthquake disasters are taken into consideration. Studies on socio-economic aspects of disasters and proposals to the administrative organizations are also discussed.

1. Introduction

Chapter 2 of this paper is the revised and shorten paper which was submitted to the International Seminar on Regional Disaster Prevention held in Tokyo September 1986 under the title of 'Basic Studies on Earthquake Disaster Prevention for Tokyo District' by same authors. Discussions on socio-economic aspects of disasters in general and proposals to the administrative organizations concerned are supplemented, which is simplified English version of the paper by Nakano published in Comprehensive Urban Studies of Center for Urban Studies, Tokyo Metropolitan University in 1986.

Basic surveys on earthquake disaster prevention by the authors and their colleagues over 50 persons have been carried out for over 20 administrative organizations can be grouped into types as follows:

Type A : General view of the problems on disaster prevention of the areas concerned.
Type B : Damage estimation due to future earthquake.
Type C : Danger degree of the areas concerned.
Besides, Type D : Basic studies on earthquake disasters of Japan and overseas are undertaken at Center for Urban Studies.

Basic surveys of Types A, B and C have been carried out basing on Basic Low on Disaster Prevention and By-laws, ordinances and regulations. The results of those surveys have been used as basic data for planning of regional disaster prevention, evacuation, urban renewal, *etc*. Unfortunately, however, from scientific point of view, those basic surveys have certain limitations such as shortage of basic data, budgets, time,

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etc., and basic and constantly continuing studies are necessary. Basic studies at Center for Urban Studies aim fundamental research and the results will be applied for basic surveys for the administrative organization.

Major subjects surveyed and studied are grouped into types as follows:

a. Seismological aspects.
b. Seismoengineering aspects.
c. Damage analysis of past earthquake disasters and the application to estimation of furture damage.
d. Socio-economic aspects.

Basic thought is to make clear the regionality and recurrency and/or time-space sequential change of disasters basing on regularity or relationships among the factors concerned with earthquake disasters. The authors believe that studies on socio-economic aspects of earthquake disasters and flood disasters have to be enforced through the experiences on not only earthquake disasters but also flood disasters.

The authors would like to dedicate this paper to the late Professor Yoshio Watanabe, who continuously encouraged the development of Center for Urban Studies.

2. Studies on Earthquake Disaster Prevention for Tokyo District

Earthquake disaster prevention for Tokyo District has been thought as primarily important task for national and local governments concerned, because Tokyo is the capital of Japan and the international center, where political, economic and social functions are concentratedly gathered. The inhabitants in Tokyo and its surrounding areas are over 25 million.

Basic surveys on earthquake disaster prevention are planned by the administrative organizations and usually executed by the consaltants in cooperation with university specialists. The authors have worked out in such projects for long years.

Procedures in such surveys are usually as follows:

a. establishment of model earthquake.
b. studies on landform, subsurface geology and seismological characteristics including historical earthquake disasters.
c. damage analysis of buildings, civil engineering and industrial facilities including fire disasters.
d. analysis of damage affected by liquefaction.
e. application of the results of c. and d. to damage estimation.
f. analysis of the dead and the injured.
g. estimation of socio-economic damage and indirect influence.

Establishment of model earthquake (Nakano and Matsuda, 1980; Enomoto and Mochizuki, 1985)

Usami, T. has analyzed the earthquakes which have shocked the city of Tokyo at an intensity of 5 or more on the Japan Meteorological Agency (JMA) Scale (nearly equal to that of 8 on the Modified Mercalli Scale) since 1600 and has shown that there was a total of 37 such earthquakes. Because of the fires that followed them, damage was especially extensive in the Ansei earthquake of 1855 and the Great Kanto earthquake of 1923. A distinction is made, however, between the two earthquakes: in the case of the 1855 earthquake, the destruction of houses was due more to the direct impact of ground motion than to fires while fires were the chief cause of the destruction in 1923.

Major earthquakes in the Tokyo area usually originate in and around the transform fault along the eastern edge of the Sagami Trough which stretches from Sagami Bay to waters south of the Boso Peninsula. Magnitude of the Genroku earthquake of 1703 was 8.2 on the Richter Scale and that of the Great Kanto earthquake was 7.9. The Ansei earthquake and the earthquake of 1894 were less intensive than the Great Kanto earthquake and the Genroku earthquake. Nonetheless, they inflicted devastating damage on Tokyo because their foci were directly under the metropolis.

The Great Kanto earthquake of 1923 is thought to be as model earthquake to examine future earthquake disasters in Tokyo district, because it affected the whole Kanto area and a big earthquake which epicenter is near the Sagami Trough is more likely to occur.

Inland-type earthquake of less magnitude ($7 \pm \alpha$) should also be taken into consideration, because of higher possibility of occurrence.

Studies on landform, subsurface geology and seismological characteristics (Matsuda, 1974; Kaizuka *et al*., 1977)

Qualitative analysis can be achieved basing on micro-landform classification. However, it is necessary to introduce quantitative analysis. For instance, damage degree by micro-landform unit or depth of subsurface geology should be taken into consideration.

In case of the Tokyo Lowland, the Recent deposits are formed through the transgression occuring after *ca*. 20,000 to 15,000 years B.P. They are divided into two members, upper and lower, by the middle sand bed, in addition to the lowest buried valley floor gravel. The lithofacies of the lower member is characterized by abundant organic matter and remarkable facies changes of sandy and clayey materials. In contrast, the upper member is characterized everywhere by widespread homogeneous marine clay and deltaic sand. The thickness and lithofacies of the recent deposits are determined by the buried topography beneath them. The buried topography has been classified into three types: (1) buried abrasion platforms at two levels, −10 m and −20 to −30 m; (2) buried river terraces at two levels, −30 m and −40 to −50 m; (3) buried valley floor cut down to −60 m to −70 m between *ca*. 20,000 to 15,000 years B.P.

Subsurface geological conditions are determined by the characteristics and thickness of the late Pleistocene and Holocene deposits. These deposits are classified into some units which have nearly uniform lithofacies and engineering properties, that is, they have specific density and secondary wave velocity. Ground type is determined by the configuration of these units. Though about 100 ground types are found in Tokyo, they are arranged in 18. Frequency response analysis was done for these 18 types by using the multi-reflection method. As a result, predominant frequency and response amplitude were calculated. It is often seen that the Japanese wooden houses which have been built on the ground showing small predominany frequency and high response amplitude are easy to be collapsed by an earthquake. Eighteen ground types were classified into 5 grades on the basis of predominant frequency and response amplitude. Roughly speaking, Grade 5 zone corresponds to weakest zone against liquefaction due to earthquake and no liquefaction in Grade 1 zone. Grade 5 zone corresponds also to the zone of buried valley floor cut down to −60 to −70 m.

Land subsidence (Nakano and Matsuda, 1976; Matsuda, 1980)

Acute land subsidence immediately after strong earthquake is known in the Alluvial plain. It is also fact that lands below sea level have been formed by land subsidence due to withdrawal of ground water in such urban areas as Tokyo, Nagoya, Osaka, *etc.* Lowest land surface is now deeper than −3 m.

In the Tokyo Lowland, the land lower than the high tide level invades about 3 km inland-ward from the coast. The land below the mean sea level came into existence around 1930 and continued to expand gradually. Its area reaches about 68 km^2 now. The land below the high tide level covers an area of about 125 km^2, of which about 32 km^2 are located below the low tide level.

The people in the Tokyo Lowland are apt to suffer three types of flood disaster. The first is a flood caused by a storm surge, an influx of high water driven by a typhoon. Destructive storm surges rushed over the Tokyo Lowland eight times since 1900. A heavy rainfall is apt to cause inundation in a lowland. Because a water level of rivers and canals is higher than land surface, rainwater cannot drain away. Such flood disaster is the second type. The Tokyo Metropolitan Government constructed continuous high embankments along the coasts of Tokyo Bay, Sumidagawa River and Arakawa River and built up pumping stations and water gates. Countermeasures for these two types of flood have been almost accomplished in the Tokyo Lowland where has been little damaged since 1966. The last type which may be severest will be induced by a strong earthquake. If the embankments or the riverwalls are broken by an earthquake, sea water or river water will rush into the land below sea level. A part of Niigata City was under water for about two weeks when the embankments along the Shinanogawa River were broken by liquefaction of sandy deposits caused by the Niigata Earthquake of 1964.

Damage analysis for applying to damage estimation (Mochizuki *et al.*, 1982; Matsuda *et al.*, 1982; Mochizuki and Goto, 1983; Mochizuki *et al.*, 1984)

Analysis of buildings damaged has been conducted by many building engineers. Particularly, damade ratio of wooden houses has been thought as an important indicator of seismic intensity, because of wide spread distribution.

Seismic intensity distribution of the Great Kanto earthquake was analyzed in order to obtain basic data for seismic risk zoning. For explaning seismic intensity distribution, the minimum distance from the fault plane which generated the Great Kanto earthquake was inferred and seven types of landform areas representing particular ground conditions were used.

Matsuda *et al.* (1982) tried to explain the seismic intensity by using the minimum distance to the fault plane and landforms which represent subsurface geological conditions. The landforms of the Kanto region can be classified into eight categories of landform area of (a) deltaic lowland, (b) valley flat, (c) coastal plain, (d) alluvial fan, (e) terrace, (f) hill, (g) mountain and (h) volcanic landform. Geologically, (a), (b), (c) and (d) roughly correspond to Holocene, (e) to Pleistocene, (f) to Tertiary and (g) to Mesozoic or Palaeozoic. Volcanic landforms, however, were classified as belonging to other landform areas corresponding to the peculiar geological conditions. For example, depositional landforms composed of pyroclastic flow were put together with terraces.

The deltaic lowland shows the highest value of K, seismic intensity defined by Mononobe, followed by the valley flat, coastal plain and alluvial fan in descending order. This order is very reasonable from the geomorphological and the seismic engineering points of view, because deltaic lowlands are composed of thick sandy-muddy deposits, coastal plains consist of sandy deposits and alluvial fans are composed of gravelly deposits. Materials composing valley flats are usually muddy but their thickness are thinner than those of deltaic lowlands. Seismic intensity is reasonably related to the minimum distance from the fault plane for each landform area.

Analysis of damage affected by liquefaction (Tajime and Mochizuki, 1965)

Attention should be drawn to affection of liquefaction in damage analysis of building of lowland area. It should be made clear the areas of liquefaction, intensity of liquefaction, damages due to liquefaction basing on data to examine liquefaction on engineering soil.

Basic procedure to identify liquefaction was formulated basing on damage analysis of wooden houses after the Niigata earthquake of 1964. The areas of liquefaction will be able to make clear using engineering soil data. Soil test sites are not always densely distributed and micro-geomorphological interpretation of aerial photographs and topographical maps are important to map out the zone of liquefaction. Unfortunately, however, micro-geomorphological characteristics are apt to be hidden by urban establishments in urban area. Old topographical maps and aerial photographs are useful for mapping of the zone of liquefaction. Detail map of the area prone to liquefaction is not completed yet.

Analysis of the dead and the injured (Matsuda *et al.*, 1981)

Relationship between the number of damaged wooden houses and the dead or the injured has been set up in several equations by different disasters of earthquake, flood and land collapse. The results are applied for the estimation of the dead and the injured in future earthquake disasters for Tokyo and other urban areas.

Damage estimation and socio-economic aspects of earthquake disaster

Generally speaking, studies on natural disasters should be achieved not only from the viewpoint of physical sciences and technology, but also from the standpoint of socio-economic sciences, because natural disasters are socio-economic matters. Simultaneously, studies on disaster prevention should be done not only for administrative organizations, but also for the people living in the area concerned.

In such urban areas as Tokyo, Yokohama, Kawasaki, *etc.*, earthquake disaster prevention is one of the most important task for the administrative organizations. Though the occurrence possibility of a great earthquake is low, if such gigantic urban areas are hit by a great earthquake now, what may happen? Some characteristic aspects of earthquake disaster will be as follows:

a. The shake of earthquake will cause the direct damage such as collapse of wooden houses, destruction of network of water supply, *etc*.
b. The direct damage will induce the secondary damage such as spread fires, floods of lowland, *etc*. especially, fires followed an earthquake will dominate the total amount of damage in case of earthquake disaster of Japanese cities.
c. The influence structure of damage and restoration process concerning people's behavior and livelihoods in a residential area of a metropolis are arranged by Nakabayashi in charts, which explain the flow of damage and human behavior from the occurrence of an earthquake and propagating process of disaster to the restoration of livelihood in each family. The restoration of people's livelihoods will take longer time relatively to the lag of restoration of such life-line network facilities as water, gas and electric supply.
d. The activities of people are very complicated in space and time, because the built up areas of Tokyo have spread over 50 km sphere. In addition, so many people will be suffered. The number of sufferers, who will lose their living house or place of work by collapse, fire and flood, are estimated to be 1,240,500 households or 3,499,200 residents in Tokyo ward district. And also the numbers of the dead and the injured are estimated at 35,700 and 63,000, respectively. The figures mentioned above are reported by the Tokyo Metropolitan Government.
e. Tokyo is the center of not only national but also international political and economic managements. The damage of this central function, especially its support systems such as new-information system, will cause the confusion of administration and economy. The restoration of these central functions will be determined by the rapidity of restoration of people's livelihoods.

As above mentioned briefly, some socio-economic aspects of earthquake disaster can be analyzed and estimated qualitatively. However, the quantitative analyses of them are a future problem. Additionally, though they are very important problems, analyses of restoration process of people's livelihoods and of interrelations among the various urban functions remained in future, too.

3. Future Study Problems Related to Urban Disaster Prevention and Proposals to Administrative Organizations

Through our experiences on disaster prevention studies including flood disaster, following points should be mentioned (Nakano *et al*., 1974; Nakano, 1976, 1980; Nakano *et al*., 1980; Nakano, 1983, 1984).

a. Studies on socio-economic aspects of disasters should be enforced.
b. The process and mechanism of growth and accumulation of damage potential in urban areas should be made clear. Even under various legal control for disaster prevention, damage potential in and around urban areas is not always decreasing. Legal structure of disaster mitigation and its application should also be reex-

amined in order to raise up ability of disaster prevention.

c. It is not so easy to mitigate damage due to disaster only by structural adjustment. Though the understanding on the necessity of nonstructural adjustment, adjustment of the people should not be over estimated, because of certain limitation.
d. Integration of research findings should be enforced. Progress of individual research, particularly of science and technology, is remarkable, but integration of research findings is still not so synthetic.
e. Studies on damages from the standpoint of social science should be encouraged. For example, monetary loss by different disasters should be made clear.
f. Urban policies should be enforced from the view point of disater prevention. For example, road systems in urban areas in Japan is very poor. Without improvement of road systems as skelton of the built-up areas, danger of fire following an earthquake will not be mitigated.
g. Recognizing the importance of basic data such as maps, aerial photographs, statistics, reports on disasters, systematic documentation on disasters covering not only physical side but also socio-economic side should be encouraged in corporation with national and local governments.

Previous representative results

The statements a. to g. mentioned above are the brief summaries of the previous studies by such specialists as White (1974), White and Haas (1975), Kates (1977, 1978, 1983 and 1985), Gerasimov (1984), *etc*. Following findings will be important as the background.

a. Ratio of monetary loss againt GNP by natural disasters is usually less than 1 percent in developed countries, and several percent or sometimes more than 10 percent in developing countries.
b. In past 20 years, annual average number of the dead is statistically small in developed countries and 5–10 times or more in developing countries. Particularly, the number of the dead due to drought and famine and the number of dead caused by flood are usually higher than that by earthquake.
c. In developed countries, the number of the dead is decreasing and the number of the injured is remarkably increasing. Decreasing number of the dead will be the result of development of warning system, and increasing number of the injured will be explained by the increase of such living goods as various furnitures, cars, *etc*.
d. Monetary loss is remarkably increasing in developed countries, because of increasing living goods and various installations and establishments.
e. Recently, damages in the mountain and hill regions are increasing, because of man-made changes of land surface.

Expecting progress of social scientific studies on disaster prevention

Social scientific studies on disaster prevention have come active particularly in America. In Japan, social scientific specialists including psychologists, sociologists, economists, *etc*. are recently participating in studies on disasters and disaster prevention. Unfortuantely, however, science and technology are still keeping majority in disaster studies.

Disaster prevention will be able to say the accumulation of disaster-experience. Social scientists should analyze and summarize the experiences of the people in the areas concerned and of the administrative organizations.

Present high attainments of scientific and technological studies on disaster prevention are not always reflected to such various establishments as buildings, lifelines, civil engineering facilities, *etc*. The administrative activities on disaster prevention are also not always perfect. Importance of the development of science and technology related to disaster prevention should not be ignored. However, social scientific studies on disaster prevention should be taken into consideration in order to improve the vulnerability of urban regions where are filled up by technological products.

Attention should be drawn to the importance of reexamination of administrative organization on disaster prevention. Generally speaking, the administrative organi zations are organized for the ordinary administrative tasks. Vulnerability of urban structure and function has been formed through the daily business. If the vulnerability of urban structure and function in an emergency case can be perfectly avoided by daily business, no risk will happen.

It is necessary to set up permanent administrative section or division which is responsible for disaster prevention. The administrators belonging to such section or division should carefully study how to mitigate damage and loss due to natural hazards, because administrative organization is responsible for disaster prevention for the people. In order to improve the present situation of the administrators, training and education for them are basically important. They should learn what is disaster in the regions damaged, because disaster prevention is the stock of experiences.

4. Concluding Remarks

The administrative organization should study why natural hazards result disasters. In this respect, attention should be drawn to not only physical aspects but also socio-economic aspects. Responsibility of disaster prevention for the people are in the hand of the administrators, not always in the hand of scientists and technologists.

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