the 25th Anniversary of the 1999 Chi-Chi Earthquake

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Future Agenda for Securing Urban Performance Against Earthquakes

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In the year of 2023, on the occasion of the 100th anniversary of the Great Kanto Earthquake, I would like to write down my personal views on future issues from the field of earthquake engineering, especially the necessity of research on multiple hazards and of the concept of ensuring the performance requirements of urban cities. This note can also be applied to the city of Taipei, on the occasion of the 25th anniversary of the 1999 Chi-Chi Earthquake.

1. Lessons learned from the Great Kanto Earthquake

On September 1, 1923, before noon, an earthquake of magnitude 7.9 occurred directly below the epicenter from the southern Kanto region to the Boso Peninsula, and the area with a seismic intensity of 7 reached not only directly above the epicenter but also the downtown area of Tokyo. At the time of the earthquake, braziers were used to prepare lunch, and it is reported that the wide-area fire caused by the collapse of many houses caused a large-scale fire breakout, resulting in more than 100,000 deaths due to the fire. The spread of the fire also led to the spread of the fire due to the fact that most of the overcrowded houses were wooden houses, and strong winds were blowing due to the low-pressure system that changed from a typhoon. Evacuation was carried out amid aftershocks, but it can be easily inferred that the presence of rivers such as the Sumida River made evacuation difficult. Edo, a name of old Tokyo city, has long been famous for fires, but it has never experienced such simultaneous fires in many places in the past.

As a reconstruction measure, earthquake-resistant and non-combustible houses were actively promoted. The following year, in 1924, the Urban Building Law (promulgated in 1919) was amended, and the provisions of Japan's first earthquake resistance standard (allowable stress design with a horizontal seismic intensity of 0.1) were included, and it became the prototype of the earthquake resistance provisions of today's Building Standards Law. In addition to making houses non-combustible, fireresistant buildings (reinforced concrete, storehouses, and bricks) were recommended as fire countermeasures, and measures to prevent the spread of fire included widening of roads and development of green belts.

2. Report of the 2024 Noto Peninsula Earthquake

Just before the sunset of January 1, 2024, a large earthquake with M7.6 occurred in the Noto Peninsula region. The reverse fault systems with 150 kilo meter long displaced near the top end of the peninsula, resulting in about 250 people death. Most of the victims were crushed by the collapse of old wooden houses covered with heavy Japanese tiles under the low temperature conditions. More than two third of the victims are 70 years and older aged people. Many roads connected to the

devasted areas were closed for several weeks due to landslides, surface cracks and deformation of roads, most of which run along the coastal line. Infrastructures such as electricity and water supply were heavily damaged. Due to the geographical condition as a peninsula, it took a few months to recover.

3. Characteristics of earthquake disasters

As can be seen from the Great Kanto Earthquake and the recent Noto earthquake, earthquake disasters are characterized by the following characteristics, unlike other natural disasters;

(1) Widespread nature of damage, (2) damage stemmed from common cause, (3) concomitant nature of various hazards, and (4) large uncertainty.

(1) It is characterized by the widespread damage caused by earthquakes. The affected area of an earthquake depends on the magnitude of the earthquake. The damage caused by the 1995 Hyogo Earthquake (M7.3) was concentrated in parts of Kobe City and Osaka City, but the Tohoku Earthquake (M9.0) caused a lot of damage from Hachinohe region in the north to Chiba Prefecture in the south, as well as in Tokyo Metropolitan region. The extensive damage means that once a disaster occurs, it is not easy to evacuate, and support from the surrounding area cannot be obtained, delaying recovery activities.

(2) In the case of the earthquake, a single epicentral source causes a great deal of damage at the same time. Buildings that exist over a wide area will be subjected to a seismic inertial force proportional to the seismic acceleration and the weight at the same time. This means that even if you provide relief to the affected area, the surrounding area will also be damaged, and the backup facility will also be damaged at the same time, making it almost impossible to perform the backup function.

(3) The ground liquefies due to the shaking of an earthquake and makes it impossible to stably support buildings, the back yard slope collapses and causes landslides, and a tsunami after an earthquake occurs. Wide-area fires after damage caused by shaking are also extremely difficult to handle.

(4) As a characteristic of earthquake phenomena, it is difficult to predict their occurrence, and even when they occur, it is impossible to know their magnitude in advance, which is accompanied by a large degree of uncertainty. Unlike the arrival of typhoons, heavy snowfalls, floods, etc., it is extremely difficult to predict their occurrence in advance.

4. Necessity of multiple hazard considerations

As a lesson from the Great Kanto Earthquake, the fires that followed the earthquake had a significant impact on the victims. Earthquake shaking causes a variety of hazards. For example, the shaking and tsunami caused by the Great East Japan Earthquake, the damage caused by the main shock and aftershocks of the Kumamoto earthquake, and the subsequent superposition of damage caused by torrential rains in the affected areas. Various hazards occurring on the time axis from immediately after the earthquake, such as damage to buildings due to earthquake shaking, landslides and liquefaction of the ground, flooding due to river damming, tsunamis, etc., combine to prolong and aggravate the damage.

Such complex hazards have not been sufficiently scientifically examined due to the

complexity of the phenomenon itself. Various concepts are being proposed, such as imposing worst-case conditions as a practical treatment, empirically considering about half of what is expected, the concept of primary and secondary hazards, combinations of hazards, chaining, and superposition, and etc. In the future, it is necessary to study methods needed for evaluating multiple hazards that occur simultaneously and consequentially in time and space.

5. Recommendations for performance-based design of urban systems

It is necessary to safely and efficiently protect urban systems (including not only the buildings and infrastructure that make up the city, but also the social and economic systems) from earthquakes, taking into account the characteristics of earthquake damage. It is necessary to clarify what to protect against earthquakes (clarification of required performance), how to protect it (selection of damage mitigation measures, whether to guarantee them by design, disaster prevention planning, etc.), and to what extent to protect them (setting the required level) before effective damage mitigation. If we consider the required performance of urban systems for earthquakes, we can think of 1) various ways of thinking about the required performance of cities, but the basic performance requirements for earthquakes are (1) protection of human life, (2) preservation of social infrastructure, and (3) continuity of socioeconomic activities. As a method of ensuring these required performances, it is possible to consider domains that can be dealt with by the seismic design of the facility, domains that are more appropriate to respond to with disaster prevention measures, and domains that respond to emergencies after a disaster. These issues need to be addressed in a cross-disciplinary manner beyond the fields of architecture and civil engineering.

6. Conclusion

Reinsurance companies have reported that Tokyo metropolitan areas are the world's worst cities for natural disasters. In addition to the high frequency of earthquakes, tsunamis, typhoons, river floods, landslides, etc., Tokyo metropolitan areas are also the center of business around the world, where a large number of people live in overcrowded conditions, and the impact of disasters on overseas is significant. It is desirable to effectively reduce risks according to the performance requirements and required levels of the city, and it is desirable to reduce risks in a balanced manner by combining the urban design stage, disaster prevention measures, emergency measures, and medium- to long-term response measures after a disaster.