SERIOUS DAMAGE DUE TO URBAN EARTHQUAKE TSUNAMI DISASTERS

-TOU-NANKAI AND NANKAI EARTHQUAKE TSUNAMI DISASTERS-

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Most seismologists of our country predicted that next Tou-Nankai and Nankai earthquake will occur around 2040. Tou-Nankai and Nankai earthquake are twin earthquake because the twin occurred eight times after 684 AD. and in the worst case, it simultaneously broke. If they occur at the same time, damage will be huge. Gigantic tsunamis as well as strong ground motion will hit every coastal city and town located between the Izu peninsula and Kagoshima Prefecture facing the Pacific. Especially, in Osaka, highly densely populated lowland areas with underground urban facilities such as subway network and shopping mall, the damage may be unbelievable huge.

Key Words: *tsunami, urban tsunami disaster, Tou-Nankai earthquake, Nankai earthquake, tsunami flooding, catastrophic disaster*

1. INTRODUCTION

Earthquake occurrences in western Japan are caused by earthquakes that occur beneath the sea along the Nankai trough. This trough is a trench of an average 4,000m in depth in the Kii peninsula that runs east to west, with its eastern tip reaching into Suruga Bay. Here the northerly Philippine Sea plate is slipping and subducting beneath the Eurasia plate at an average speed of 4cm/year, and is believed to have been doing so for millions of years. When this slippage exceeds a total of about 5m, a rupture occurs, creating a magnitude 8 to 8.6 earthquake.

This paper presents disaster scenarios that are necessary for producing a long-term tsunami measure policy and which, more importantly, have not yet been encountered in actual tsunami disasters.

2. CURRENT TSUNAMI DISASTER RESEARCH

2.1 Recent tsunami disasters

Tsunami disasters have occurred frequently throughout the 1990s all around the world. Earthquake-generated tsunamis have struck successively over recent years, in Nicaragua in September 1992, Indonesia's Flores Island in December 1992, the Hokkaido Nansei-oki in July 1993, East Java in June 1994, and the Hokkaido Toho-oki in October the same year. They also struck Northern Sakhalin in May 1995, and Irian Jaya, Indonesia in February 1996. The common factor in all of these events was that the damage was confined to coastal villages and fishing harbors where the maximum population living on the tsunami flood areas was only about one thousand people. However, the "urban tsunami disaster" due to occurrence following earthquakes in the Tou-Nankai and Nankai is expected to strike a wide area that includes modern coastal cities and ports, resulting in a disaster of unprecedented proportions. Consequently, experts think it will be very difficult to apply the lessons of past tsunami disasters if an expansive area including residential coastal towns as well as low-lying urban regions with populations of hundreds of thousands or millions of people is hit by a tsunami.

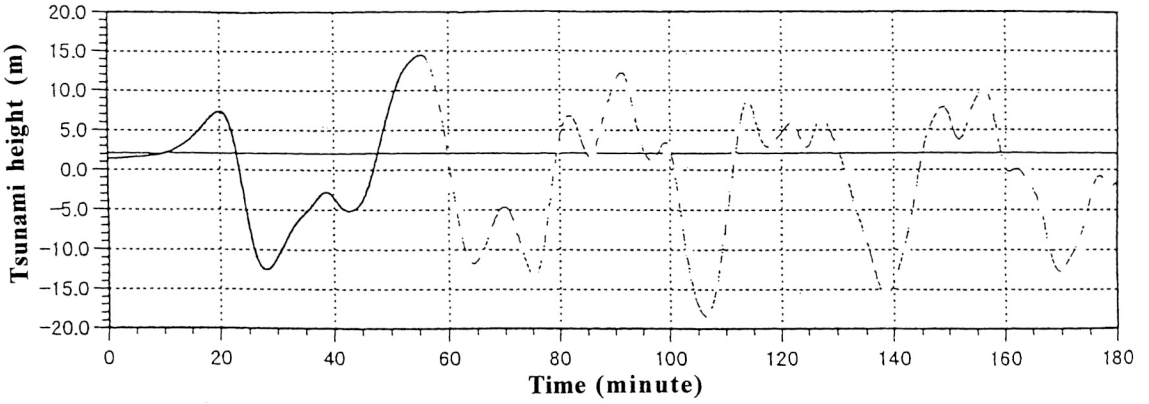

Fig. 1 Calculated waveforms from the hypothetical Tou-Nankai tsunami (Owase)

2.2 Recent efforts in tsunami disaster research

Because the purpose of tsunami disaster research is to minimize damage, research specifically pertaining to damage control is a top priority. To minimize injuries and casualties, individuals must evacuate the compromised region immediately following an earthquake. To evacuate, people need to have received accurate information regarding the tsunami threat ahead of time. The public needs the kinds of information presented below.

1) What size tsunami should be expected where I live ? Will my house be in danger ?

2) How long after an earthquake will a tsunami arrive ? The hypocenter of oceanic earthquakes are not fixed;

3) How long will it take for the tsunami to hit ? How long will it continue ? **Figure 1** shows the tsunami waveforms in Owase, Mie Prefecture caused by the magnitude 8.4 Tou-Nankai earthquake. The second wave in this case was 40% larger than the first. It was reported that after the 1944 Tou-Nankai earthquake, residents who survived the first wave returned to their homes to gather their valuables only to be caught in the second wave.

4) What is the worst case scenario should a tsunami strike our community ? In a tsunami disaster, the first principle to follow is for each individual to look out for themselves. The next is for each community to look out for itself.

The authors have tried to solve these problems by using the finite element method. One of the result is shown in **Fig. 2**. These examples were applied Hiro-cho in Wakayama Prefecture, the sites of the "Inamura no hi" described in nationally prescribed textbooks prior to World War II. This Figure shows the regional distribution of floodwater depth from the tsunami that resulted from the 1854 Ansei Nankai earthquake based on the current topography of this region. The minimum value calculated for one side of the triangle is 2m, and it takes into consideration minor waterways, the location of buildings, and a complex road network.

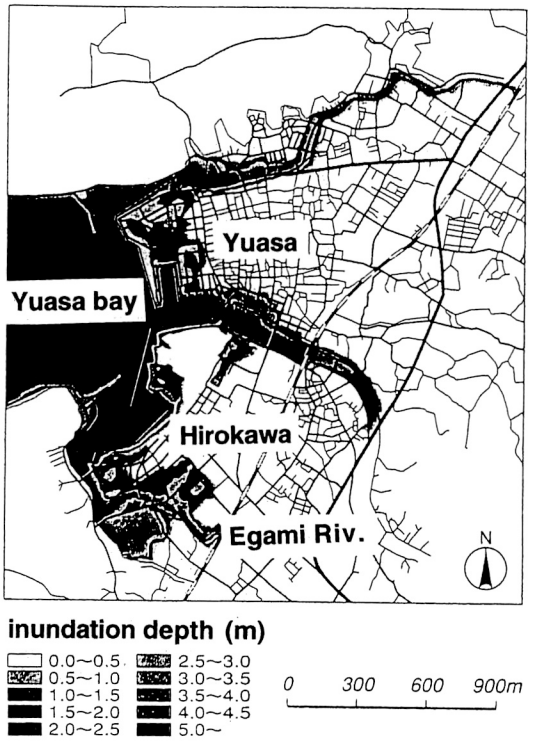

Fig. 2 Flood calculation results for the 1854 Nankai earthquake-generated tsunami in Hiro-cho, Wakayama Prefecture

3. NEW DAMAGE SCENARIOS FOR URBAN TSUNAMI DISASTERS

First the reason for the use of the term "urban" is necessary. A list of the tsunami disasters that have occurred in modern Japan in the order of greatest casualties caused would appear as follows:

No.	YEAR	TSUNAMI	CASUALTIES
1	1886	Meiji Sanriku tsunami	21,959
2	1933	Showa Sanriku tsunami	3,068
3	1946	Nankai earthquake tsunami	1,330
4	1944	Tou-Nankai earthquake tsunami	1,223
5	1993	Hokkaido Nanseioki earthquake tsunami	230
6	1960	Chilean earthquake tsunami	142
7	1983	Nihonkai-cyubu earthquake tsunami	104

However, these numbers include casualties caused by the related earthquakes as well. The areas affected by all of these tsunami disasters were local fishing villages or harbor towns with populations in the tens of thousands or less, not modern and densely populated port cities. This tends to be the case around the world; past tsunami disasters have all occurred in relatively rural areas. However, it is possible that the next Tou-Nankai and Nankai earthquakes will cause serious damage above and beyond what has been seen in past tsunami disasters. New hypothetical damage scenarios are described below.

1) Possibility of a tsunami that exceeds estimates:

The wave height and arrival times of the hypothetical tsunami were calculated based on a magnitude 8.4 earthquake with the same hypocenter as the Showa Tou-Nankai and Nankai earthquakes. Thus, there are at least two possible tsunami scenarios that would exceed current estimates. The first would be if the earthquake hypocenter were to shift eastward or westward, and the second would be if the earthquake were of a magnitude greater than 8.4. Seismographic records showing the earthquake's hypocenter are only available for the 1946 Showa Nankai earthquake. The hypocenter for earthquakes of magnitude 8 or larger prior to this have been estimated from the attributes of the resulting tsunamis. Accordingly, their accuracy is not as reliable as that of the Showa Nankai quake. These results suggest that the hypocenter may be distributed over a 200km east-west stretch. On the other hand, indications suggest that fault ruptures from a Tou-Nankai or Nankai earthquake occur not in a disorderly fashion, but that they have a definite pattern. This means that it is reasonably safe to assume that the hypocenter will actually be fixed. Given thee above issues, though, the location of the hypocenter is still a topic of debate, and it is impossible to assert that it will be fixed with absolute certainty.

In the latter scenario, if a Tou-Nankai earthquake and Nankai earthquake were to occur simultaneously (as is said to have happened in the 1707 Hoei Earthquake), an earthquake of magnitude of 8.6 is estimated to occur. Calculations for this case suggest that the height of waves reaching Osaka Bay coastal regions would be 20% greater than in an 8.4 quake, while the arrival time of the first wave would not be significantly altered. Even in this case, it does not appear that the waves would spill over sea walls or embankments located in all of the outlying areas. It is still unclear whether a relationship can be established with the fault parameters for all magnitude 7 or higher earthquakes. All indications suggest that the possibility of a tsunami that will exceed current expectations cannot be ruled out.

2) Inundation flows through flood gates and sea walls:

In outlying coastal areas and areas adjacent to rivers in Osaka Prefecture, there are an estimated 900 flood gates and sea walls. With the exception of those that are directly maintained by the Prefecture and City of Osaka, most of these gates and walls are privately maintained. Although according to standard practice, they are supposed to remain closed when not in use, most of them actually tend to remain open. If a hypothetical Nankai earthquake occurs, the degree of ground motion in the outlying areas of Osaka Prefecture is expected to be about the same as that experienced in the Southern Hyogo-ken-Nanbu Earthquake. Accordingly, it may become impossible to close several of the existing flood gates and sea walls.

It must therefore be assumed that if a Nankai earthquake tsunami were to occur under the current conditions, some water would pass through the flood gates and sea walls. Past records indicate that if a tsunami hits, the upstream regions will be inundated in areas whose ground level is the same as or less than the tsunami height.Thus, areas less than 3m above sea level will be in danger of

flooding. However, since the water will be entering through flood gates and sea wall openings, the flow discharge to inundate hinterland will be determined by the product of the cross sectional area and the current velocity.

3) Damage to harbors and vessels:

Damage to port facilities by a hypothetical tsunami, caused, for example, by sea walls breaking apart, is not expected to occur as long as the tsunami does not spill over barriers. Damage may be sustained, though, if waves cause moored vessels to roll and pitch, knocking them against the wharf or running them aground. Because the tsunami would reach, for example, the southern coastal areas in Osaka Prefecture one hour after the earthquake, and Osaka harbor about two hours after the quake, it will probably be impossible to remove moored vessels from the harbors in time. In terms of injuries and casualties, at least two scenarios are possible. The first involves casualties resulting from boats underway along the coast being tossed about by the tsunami and thrown against sea walls or flood barriers. Small vessels underway upriver may encounter collapsed bridge piers or, worse, collapsed bridges.

The second scenario involves relatively large moored vessels being run aground by the tsunami. They may be swept toward the shore with successive waves and cause damage to the sea walls and other constructed barriers along the coast. Because the extent of damage in both of these scenarios depends on the size of the vessel, the larger the vessel, the larger the danger that large volumes of water will be allowed to reach the shore. Also, if any of these vessels is an oil tanker or a liquid natural gas tanke, oil or gas may leak and/or ignite, creating the potential for a widespread fire. This could cause serious damage depending on the extent of the incident.

4) Evacuees:

It is believed that since a Tou-Nankai and Nankai earthquakes would not likely fully or even half destroy houses, there would be no need for area residents to evacuate to shelters. Tsunami warnings should explain how people should respond. First, those residing in flood prone areas along the coast should go to designated emergency shelters (schools and other public facilities) or to the third floor or higher of iron-reinforced buildings in their neighborhood. Next, there are several problems must be handled and tasks that must be done once the tsunami warning has been announced. Because the tsunami will go up river, it is necessary to make absolutely certain that residents do not evacuate to areas close to the riverbed. Also, in Osaka, for example, within just under two hours after a Nankai earthquake, the south and north underground malls must be closed, the Osaka Municipal Subway, Hankyu, Hanshin, Keihan and JR-West train lines must be moved from their underground tracks to aboveground areas. Access to basements and underground parking lots of buildings must also be restricted.

4. CONCLUSIONS

This paper focused on the potential damage scenarios caused by the highly anticipated earthquake in the Tou-Nankai and Nankai, and outlined the issues being addressed in tsunami disaster research in general, as well as those being studied by the authors. An urban tsunami disaster is not limited to the kinds of tsunamis discussed above, but could occur following a Sanriku tsunami as well.