



Trend of Tsunami Evacuation Buildings against the Nankai Trough Earthquake

S. Ando ⁽¹⁾

⁽¹⁾ (1) Professor, Kindai University, ando@arch.kindai.ac.jp

Abstract

Nine years have passed since the 2011 Great East Japan Earthquake and Tsunami occurred. Reconstruction efforts for recovery are fully carried out in the affected areas along the Pacific Ocean coasts. The author has investigated actual conditions and trends of tsunami evacuation buildings (TEB) designated before and after the huge disaster in Tohoku.

The most important measures against tsunami disaster are to implement the disaster prevention projects and land use control such as housing lot relocation project, and to execute the certain evacuation measures for the inhabitants. Implementation of disaster prevention projects and announcement of tsunami-warning are studied by the national government. However, evacuation measures for inhabitants or improvement of safety elevated ground and tsunami evacuation buildings are entrusted for municipal governments that are puzzled over many problems, because they have no concrete residential land use guidelines or effective methods on certain evacuation, especially designation of tsunami evacuation buildings against the expected Nankai Trough Earthquake.

In Tohoku region before the 2011 Great East Japan Earthquake, TEBs were designated in the most affected regions in Iwate, Miyagi and Fukushima prefectures. Most of them functioned against tsunami and saved many surrounding residents. A tsunami evacuation building in Minami-sanriku Town was a public hospital with five-story and although even fourth floor was inundated, many people evacuated fifth or top floor. However, municipality of Kamaishi city retracted TEB designation even for a remained building with eight stories. It seems that heavily affected municipalities tend to be more circumspect to designate TEBs again and tend to retract TEBs.

On the other hand, less affected areas even in Miyagi prefecture or other prefectures located in western part of Japan, municipalities in the coastal area designate many TEBs especially after the 2011 Great East Japan Earthquake in Tohoku. The author shows actual conditions and analyses the background of TEBs in the affected regions as well as the regions where the large tsunamis are expected in the near future such as Nankai-Trough Earthquake.

This research paper aims at utilizing the lessons learned from the evaluation on roles of TEB at the 2011 Great East Japan Earthquake into the disaster risk management system for the coming Nankai Trough Earthquake and Tsunami as an urgent counter-measure in the future. This paper is based on the outcome of research on “Effective Evacuation Measures against Tsunami Disaster” by National Graduate Institute for Policy Studies (GRIPS) and the result of July to September 2019 Kindai University investigation on TEBs designation of whole municipalities in Japan. This paper is based on researches after WCEE16 using national research funds and the result of several investigations on TEBs designation in Japan. In addition, “Investigation on Actual Conditions of tsunami evacuation buildings etc.” by the Japanese Cabinet Office and Ministry of Land, Infrastructure, Transport, and Tourism in 2016 and 2018 are referred.

Keywords: Tsunami evacuation building (TEB), Designation, Nankai Trough Earthquake,

National Graduate Institute for Policy Studies (GRIPS), Great East Japan Earthquake



1. Research Background and Purpose

After the Great East Japan Earthquake of 2011, the assumption of the tsunami up to that time was greatly revised. This is based on the “Tsunami Disaster Prevention Community Development Act” (Law No. 123 of 2011), which states that the prefectural governor should consider the tsunami inundation (the area of land that is likely to be inundated by the tsunami and the estimated water depth when inundated). Once set and published, the assumptions were reviewed nationwide by fiscal year 2013, except for the three Tohoku prefectures that were severely damaged by the Great East Japan Earthquake due to the provisions of Article 8 of the same law.

At the same time as the enactment of the law on December 27, 2011, the government established the “Basic Guidelines for Promotion of Tsunami Disaster Prevention Community Development”, and the prefectural governments first implemented inundation assumptions. It means that a promotion plan for comprehensive measures against tsunami can be created. If this promotion plan can be made, various special measures can be applied in it, and one of them is “the floor area ratio of tsunami evacuation buildings”.

The purpose of this study is to clarify the current situation of tsunami evacuation buildings including the tsunami evacuation tower in order to further promote tsunami disaster prevention measures. Until 2015, an independent survey was conducted every August, and in 2019 continuous study was done by the author in Kindai University, while the national government carried out surveys on number of TEBs in 2011, 2016 and 2018. This study was conducted based on relevant data from the independent research and national surveys.

2. Previous Researches

Various papers have been written about tsunami evacuation buildings (TEB), especially since 2011. Prior to the Indian Ocean Tsunami in 2004, Takeuchi et al. [1], [2] conducted a study on the evaluation of evacuation sites from the viewpoint of evacuation behavior called "Empirical analysis on evaluation of tsunami evacuation sites in consideration of capacity" targeting Susaki City and disaster awareness based on GIS.

Following the Indian Ocean tsunami, the Cabinet Office published “Guidelines on Tsunami Evacuation Buildings, etc.” in June 2005 on tsunami external force evaluation called "design external force evaluation of tsunami evacuation facility based on survey results". Experimental researches on evacuation include the evacuation simulation of a tsunami evacuation facility such as “Evacuation simulation from tsunami using a multi-agent system”, Oki and Tanaka [3]. Studies on TEB also include assuming evacuation of people requiring assistance during a disaster by Watanabe and Kumagai [4] and researches on the structure of facilities, evacuation characteristics, facility layout, measures for the weak, etc. All of the studies are targeted at specific areas and facilities, and studies nationwide especially since 2011 Great East Japan Earthquake.

As can be seen from the Cabinet Office and the Ministry of Land, Infrastructure, Transport and Tourism's "Results of Survey on Tsunami Evacuation Buildings" (December 2011), the number of tsunami evacuation buildings has increased rapidly since the Great East Japan Earthquake. The lessons learned from tsunami disasters that accounted for the majority of the dead and missing have been learned in various parts of the Tohoku region. In addition, legislation has been enacted, and tsunami countermeasures have been enriched in terms of systems. His research also includes the National Institute for Land and Infrastructure Management, and “Study on Effective Evacuation Measures in Tsunami Disasters” by Takeda, Ike, Ando, and Hibino [5].

In particular, in recent years, research has begun on a wide area, mainly for measures against the Nankai Trough earthquake and tsunami. At the national level, Ogawa et al.[6] summarized the results of a survey conducted six months after the Great East Japan Earthquake. New researches such as "Analysis of actual conditions and trends of tsunami evacuation buildings nationwide" by Ando [7] a study on the architectural features and regional trends of TEBs in the supposed area of the Nankai Trough Earthquake and tsunami based on a national survey and a 2013-2014 survey by the National Graduate Institute for Policy Studies (GRIPS). Among them, Ogawa et al. [8] research was based on a questionnaire survey of municipalities.



3. Research Methods

3.1 Target municipalities

In this study, the number of targeted municipalities is 662. This is basically a municipality with a coast, but municipalities facing the inland sea, such as Lake Saroma in Hokkaido and Lake Shinji in Shimane Prefecture (specifically, Saroma Town, Hachirogata Town, Igawa Town, Ogata Village, Yasugi City, Omura City, Nagayo, Togitsu, Higashisonogi, and Kawatana Town in Nagasaki Prefecture are also included).

In addition, municipalities where tsunamis may invade from the sea through flatlands and large-scale rivers without having a direct coast (It includes 16 local governments of Sapporo, Mito, Tsubame, Kariwa, Tsubata, Kariya, Higashiura, Asahi, Izumi, Kozagawa, Fuchu, Kitajima, Aizumi, Okawa, Mizumaki, and Onga). There is a case where a TEB was designated even though there is no coast like Kozagawa town in Wakayama Prefecture (although it is abolished at present). The data is aggregated for each prefecture / city.

3.2 Definition of tsunami evacuation building (TEB)

There are three official definitions of TEB:

a) Definition by Tsunami Disaster Prevention Community Creation Act

There is "Designated evacuation facility" designated by mayor of municipality to ensure smooth and quick evacuation in the tsunami event in a tsunami disaster alert area. It is required to conform to the safe structure specified in Notification 1318 of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in 2011.

b) Definition of Cabinet Office guidelines

According to the Cabinet Office guidelines of June 2005, "Tsunami evacuation buildings, etc." refer to facilities where local residents, etc. are temporarily or in an emergency evacuation within the tsunami inundation area. It does not include evacuation facilities and hills in areas where there is no risk of tsunami.

c) Definition of MLIT Port Authority Guidelines

In October 2013, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)'s Port and Harbor Bureau guidelines defined tsunami evacuation facilities as tsunami evacuation towers for evacuees of evacuees in evacuation difficult areas and those who were delayed in evacuation, including hills.

In this study, the following two points are adopted as the definition of "Tsunami evacuation building". Note that municipalities and regions that have designated tsunami evacuation buildings before laws and guidelines were established do not always follow those national definitions.

3.3 Definition of "tsunami evacuation building" in this study

- Targeted in the 2011 national survey of TEB.
- Municipalities specified in tsunami evacuation buildings or similar names in regional disaster prevention plans, tsunami hazard maps, public relations, etc. However, even if all or a majority of the similar names are in the area where there is no risk of flooding, unless the municipalities specify TEBs separately.

List of similar names defined as "tsunami evacuation buildings" were prepared (but not attached here. Use of the name "tsunami evacuation building" is equivalent to 76.6% of the target facilities nationwide. Of the 11551 buildings targeted in 2015, there were 8845 tsunami evacuation buildings and 2632 buildings with other names, as well as 135 tsunami evacuation towers). The 39 buildings were listed in 2011 national survey, but could not be confirmed in subsequent independent surveys in 2013-2015 and 2019.

3.4 Survey method and period

The latest information was selected from the four types of publicly available data of the target prefectures and municipalities: 1) tsunami assumption, 2) regional disaster prevention plan, 3) tsunami hazard map, and 4) information on local government sites such as public relations. The same method was used in August



2013, based on an independent survey by the National Graduate Institute for Policy Studies (GRIPS) in August 2014 and 2015 and a study conducted by the Kindai University in 2019. Cabinet Office and MLIT carried out nation-wide survey on number of TEB in 2016 and 2018 following 2011 survey. However, the number of TEB includes more than 1200 flood evacuation buildings in Osaka city and the national survey does not clarify the use, structure, floor area and other data except number in each municipality of TEB.

- Survey method: Survey 662 municipalities from the following four points
 - a) Regional disaster prevention plan for each municipality: 628 municipality
 - b) Description on tsunami hazard map: 519 municipalities
 - c) Local government public relations website information: 662 municipalities
 - d) Estimated tsunami inundation information for prefectures: 39 prefectures
- Survey items: Designated number of evacuation buildings, name, location, evacuation shelter, intended use, regional disaster prevention plan, maximum expected flood depth, etc.

4. Outline of current Survey Results

Figure 1 and Figure 2 summarize the trends and the latest status of TEB in each region in whole Japan.

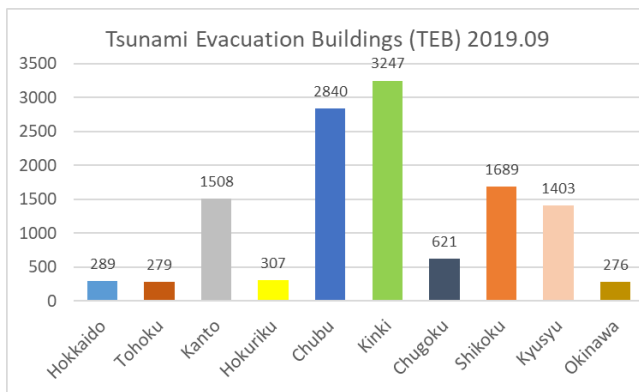
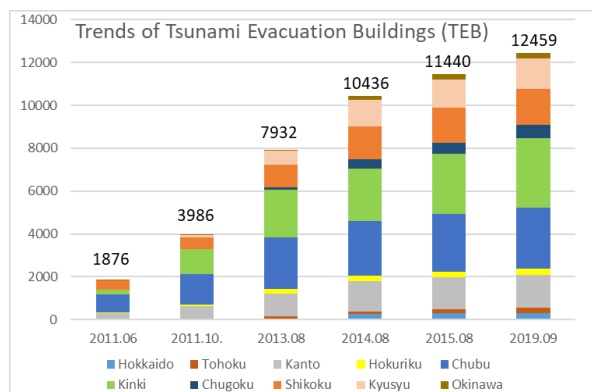


Fig. 1 Trends of TEBs by region (total in Japan)

Fig. 2 Number of TEB in each region as of Sept. 2019

First, Fig. 1 shows that the Chubu region including Shizuoka Prefecture had a large proportion of early Tokai earthquake tsunami countermeasures until 2011, followed by the tsunami countermeasures against Nankai Trough Earthquake in Kinki, Shikoku, Kyushu, Kanto and Chugoku regions. Fig. 2 shows the current situation of TEB. Kinki region has the largest number of TEB, especially Osaka city has the largest number.

Secondly, Fig. 3 also shows trends of number of TEB by region. Kinki region has exceeded Chubu region in 2015. Number of tsunami evacuation towers shows that Chubu has the largest number as shown Fig. 4.

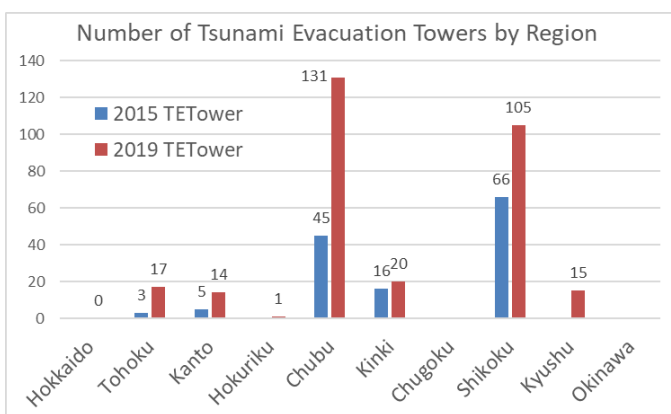
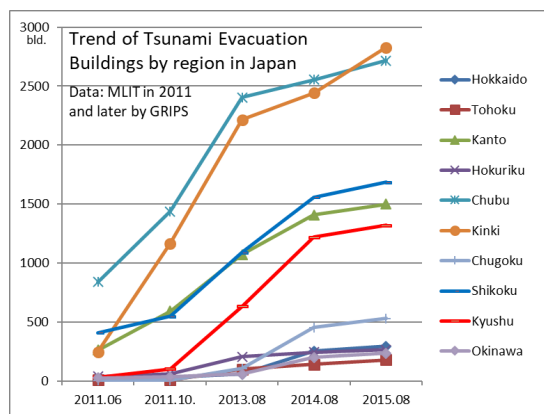


Fig. 3 Trend of TEB by region (2011-2015)

Fig. 4 Number of Tsunami Evacuation Towers (2015/19)



As for the prefectural level, number of TEB in Osaka Prefecture is the largest in Japan (2019) as shown in Fig.5. While Fig. 6 shows the trends of TEB by prefecture, Osaka Prefecture had the first position since 2014.

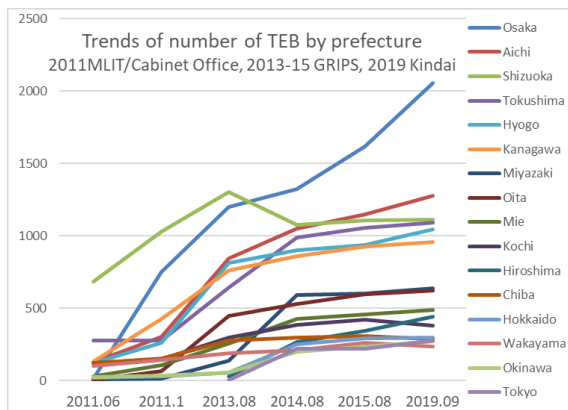
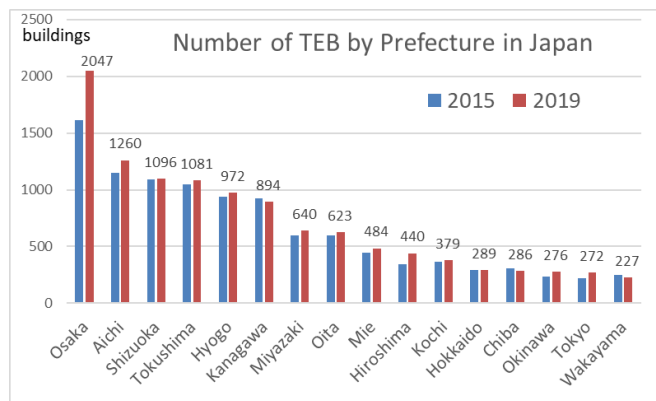


Fig. 5 Number of TEB by Prefecture (2015-2019)

Fig. 6 Trends of TEB by prefecture (2011-2019)

As for the municipality level, number of TEB can be shown as Fig.7 in all Japan in 2019. The largest city is Osaka city (1620 TEB in 2019), following Nagoya city (999), Tokushima city (706), Oita city (496), and Nishinomiya city (406). Fig. 8 shows the density of TEB in Kinki and Chubu regions. Four of top five cities are included in Fig.8.

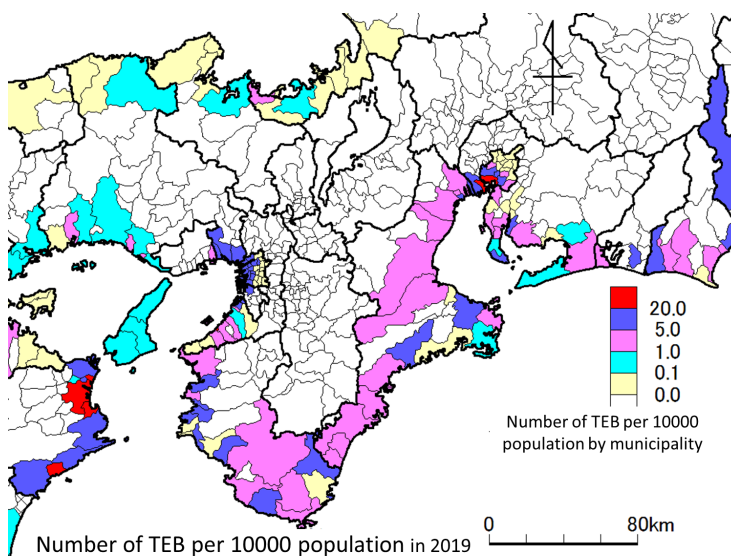
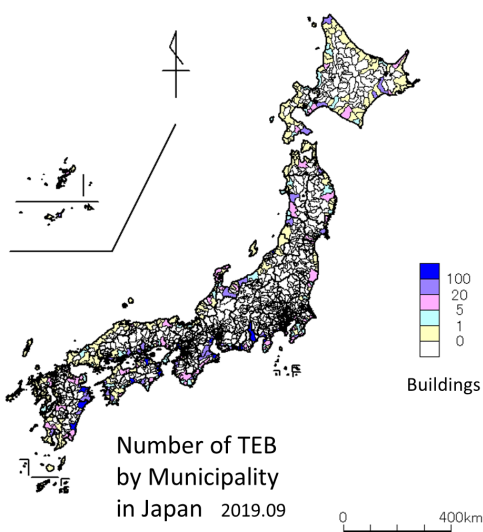


Fig. 7 Number of TEB by Municipality (2019)

Fig. 8 Density (number of TEB per population) of TEB

5. Relationship between Use and TEB Designation

5.1 Relationship with Use of TEB

After analyzing the use data in 2015, the following figures show the current situation of TEB from viewpoint of relationship between use and TEB designation.

Point 1: Many applications are for private and public housing and schools.

- Kinki has the highest percentage of schools and public housing, and Chubu has the highest percentage of private housing. The characteristics of TEB designation varies by region maybe because of the land use or building type. The reasons should be analyzed in the next studies, such as building structure, height, scale and land use, infrastructure of coastal areas and so forth.



• For other uses than schools and houses, half of the tsunami evacuation tower is located in Shikoku in 2015 as shown in Fig. 4, and 40% of the disaster prevention center is located in the central part. In addition, the ratio of government offices and hospitals is low in Kinki, and the ratio of hotels is high in Hokkaido and Okinawa.

Fig. 9 summarizes the number of TEB by use and by region (2019). The data of TEB use in 2019 is under analysis. Fig. 10 shows its proportion by region. Upper mentioned characters of TEB can be seen. Fig. 11 shows the data of use of TEB in 2015 by use and by region. The same characters can be seen as Fig. 9 and 10. Fig. 12 shows the proportion of Fig. 11.

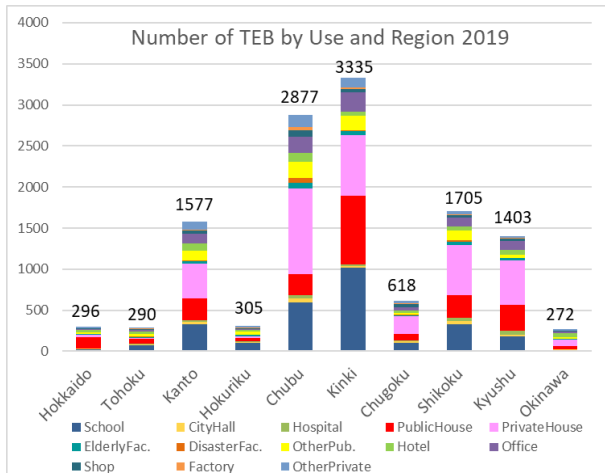


Fig. 9 Number of TEB by use and region (2019)

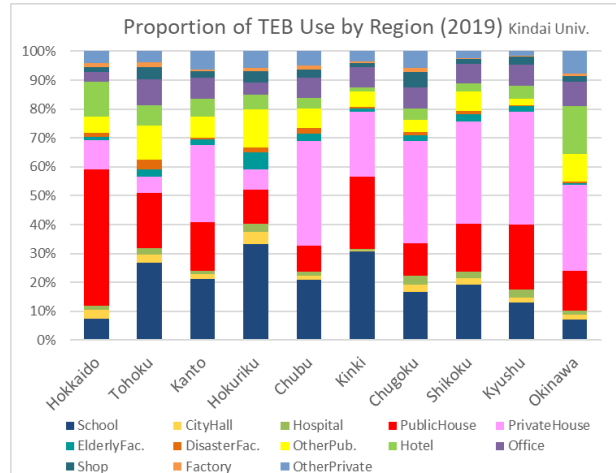


Fig. 10 Proportion of TEB Use by Region (2019)

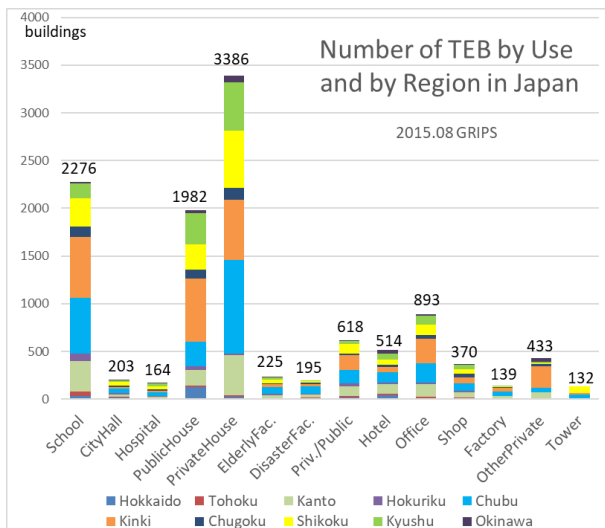


Fig. 11 Number of TEB by region and use (2015)

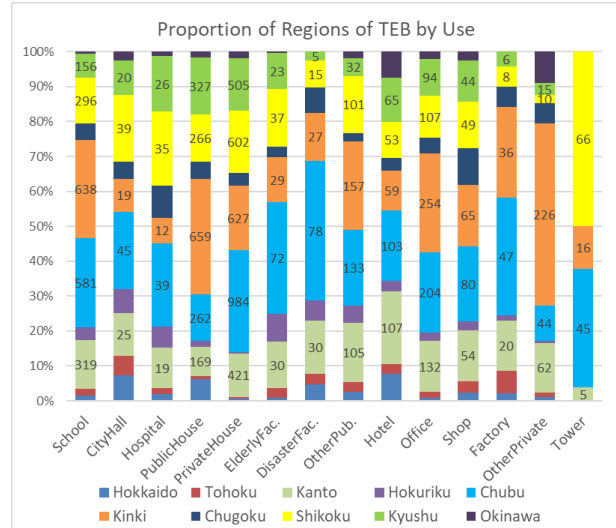


Fig. 12 Proportion of TEB Region by Use (2015)

5.2 Relationship with assumed Inundation depth

According to Figure 13, the number of evacuation buildings is increasing in all areas. There are number of TEBs especially in areas where the estimated tsunami inundation depth is 5m - 9m. The municipalities that have more than 10m maximum inundation depth did not increase the number of TEB as lower inundation is expected area.

Figure 14 also shows that the number of TEBs in the area with the estimated lower tsunami inundation depth has increased significantly, even more than 17m height tsunami is expected. The number of designated buildings has hardly increased in the area over 20m of tsunami inundation.

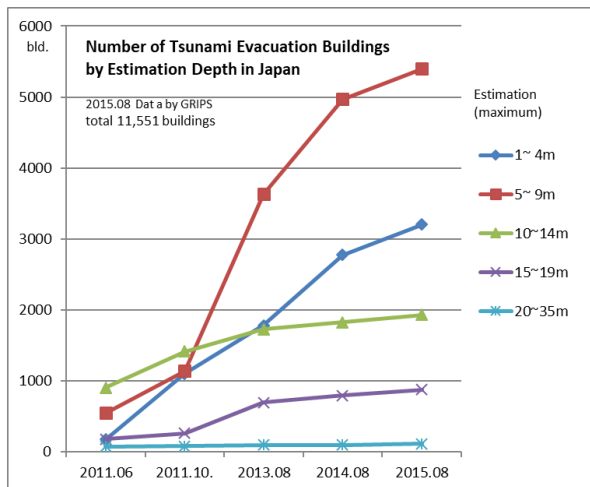


Fig. 13 Trends of TEBs by inundation depth

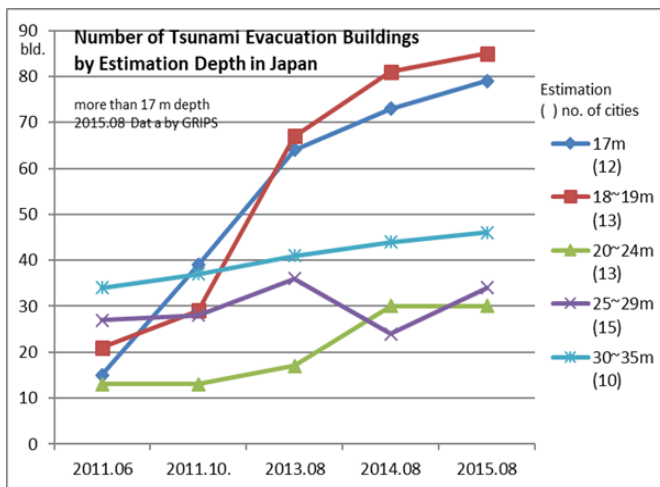


Fig. 14 Trends of TEBs by rank 5 inundation depth

6. Designated TEBs and their Use

6.1 Outline of Relationship between the Number of TEBs and their Use

In the following figures, the author classified 299 municipalities by number of tsunami evacuation buildings; 100 or more (7406 in 26 municipalities), 50-99 (1267 in 18 municipalities), 20-49 (1473 in 49 municipalities), 10-19 (829 in 61 municipalities), 5-9 (388 in 60 municipalities), and 1-4 (188 in 85 municipalities) as of Aug. 2015 in Fig. 15 and Fig. 16.

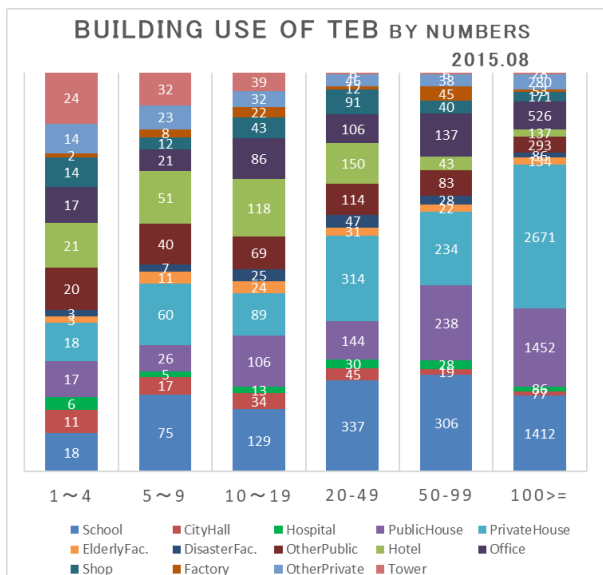


Fig. 15: Use Ratio by Number of TEB (2015)

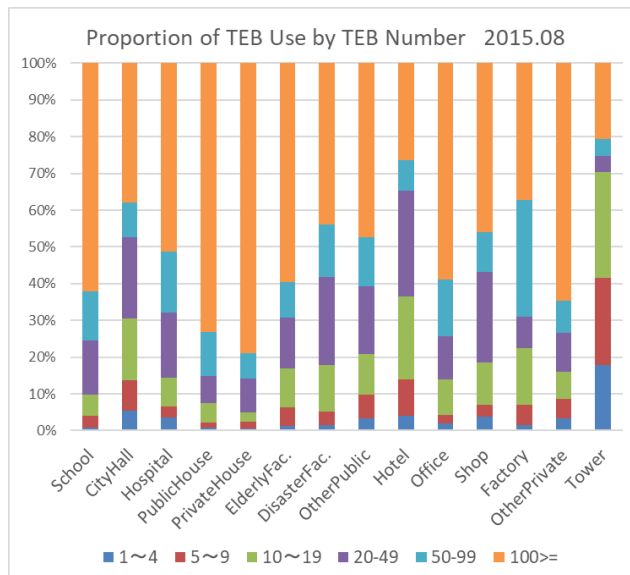


Fig. 16: Number of TEB Ratio by USE (2015)

Based on Fig. 15 and Fig. 16 above, the following status has been found regarding the designation of tsunami evacuation buildings.

- Private houses, public houses, schools have a large absolute number, and municipalities with many TEBs are specified at a higher rate.
- Government offices, hotels and stores also specify a certain percentage of municipalities with few TEBs.
- Tsunami evacuation towers are specified at a higher rate for municipalities with fewer TEBs (less than 5).



6.2 Relationship with City Size

Next, the author analyzed the designation of tsunami evacuation buildings as public facilities by dividing the city size into seven categories for the entire urban population. This classification is based on the Basic Resident Register population on January 1, 2014.

Out of 299 municipalities with TEBs, each city designated TEBs as follows. More than 1 million (2700 buildings in 7 cities), 0.5-1 million (1033 buildings in 10 cities), 0.3-0.5 million (2502 buildings in 20 cities), 0.1-0.3 million, 50,000 to 100,000 (1,146 in 56 municipalities), 30,000 to 50,000 (668 in 50 municipalities), and less than 30,000 (850 in 106 municipalities), as shown in Fig. 17 and Fig. 18. There is a high positive correlation of 0.628 between the city size based on population and the designated number of TEBs. The following describes only the features that have not been seen so far.

- Cities with a population of 500,000 or more make up more than 40% of all schools and more than 35% of public housing, but about 20% for other public uses. In particular, the proportion of large cities in the entire tsunami evacuation tower is low at less than 10%.
- Cities with a population of less than 50,000 make up only about 10% of schools and public housing, but account for 20% to 30% of other public uses, and more than 60% of all tsunami evacuation towers.

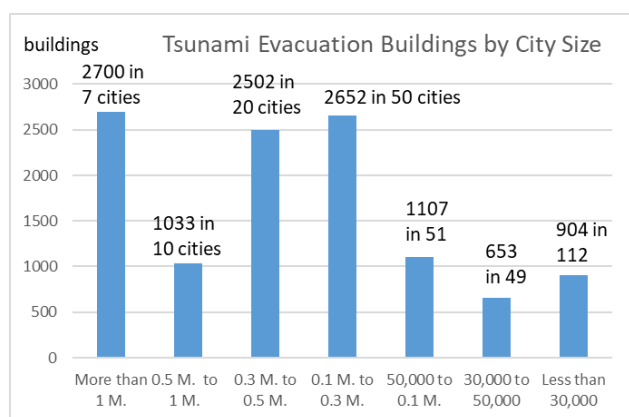


Fig. 17: Number of TEBs by city size (2015)

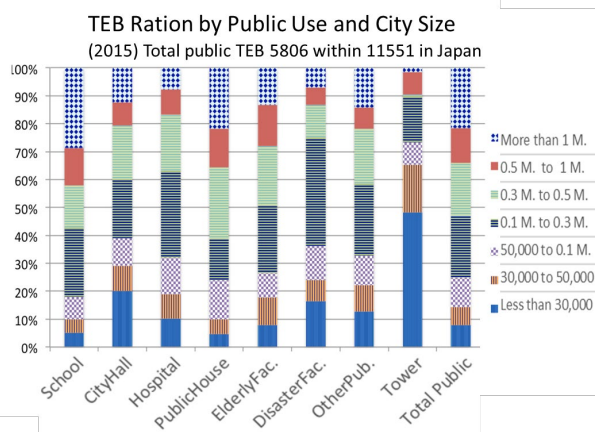


Fig. 18: TEB Rate by Public Use and City Size (2015)

In addition, the correlation will be higher if the population in the inundated area is assumed to be the tsunami-exposed population instead of the entire city. However, in this study, in order to analyze the correspondence between municipalities, the entire city population is used. (Fig. 17 and Fig. 18)

The cities with the largest number of TEBs are designated by government ordinances. Many schools are designated for the population size in Tokushima, Ise, Nobeoka, Naruto, Anan, Gobo City, Kawagoe Town, Mie Prefecture, etc. In addition, Oita City, Miyazaki City, Tokushima City, Nobeoka City, Izumiotsu City, Komatsushima City, Sakaiminato City, Matsushige Town, Tokushima Prefecture, etc. have many public housings specified for their population.

6.3 Relationship with Maximum assumed Inundation Depth

The estimated inundation depth of tsunami is prepared by prefectures. In particular, after the enactment of the Tsunami Disaster Prevention Community Development Act, tsunami inundation assumptions were made all at once except for the three Tohoku prefectures. Based on the assumption of maximum inundation, the author surveyed the breakdown of the maximum inundation depth of 662 municipalities in this study, which are located on the coast, regardless of the presence or absence of TEB. From Fig. 19 and Fig. 20, it can be seen that municipalities with a large estimated tsunami inundation depth of 11m or more, both in absolute value and proportion, are found in Chubu, Okinawa and Shikoku. Conversely, there is no risk of a tsunami



longer than 11m in the Chugoku region. Here, the areas where the large tsunami is likely to occur are the “Special Strengthening Area” and “Strengthening Area” of the Nankai Trough earthquake countermeasures.

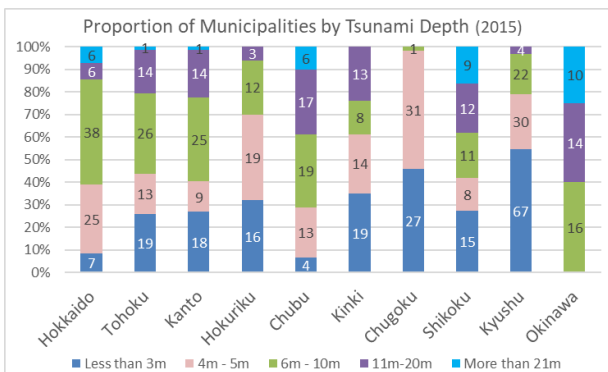
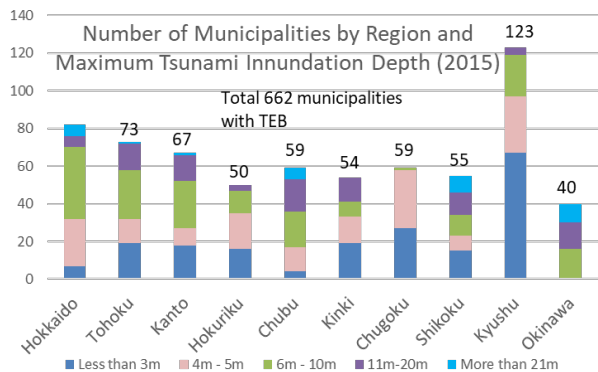


Fig. 19: Number of Municipalities by Tsunami Depth Fig. 20: Proportion of Municipalities (2015)

6.4 Current Situation in Target Areas of the Nankai Trough Earthquake

Fig. 21 shows 114 municipalities in the Nankai Trough Earthquake Tsunami Evacuation Countermeasures Specially Strengthening Area (139 municipalities in total) out of 299 municipalities with tsunami evacuation buildings. Of these, 17 cities with triangular marks have severe inundation depths of 11 m or more and tsunami evacuation buildings of 15 or more, and 16 municipalities with circle marks have 6 m or more and 10 m or less as shown in Fig. 6 and 7, municipality that meets the conditions of more than 40 buildings.

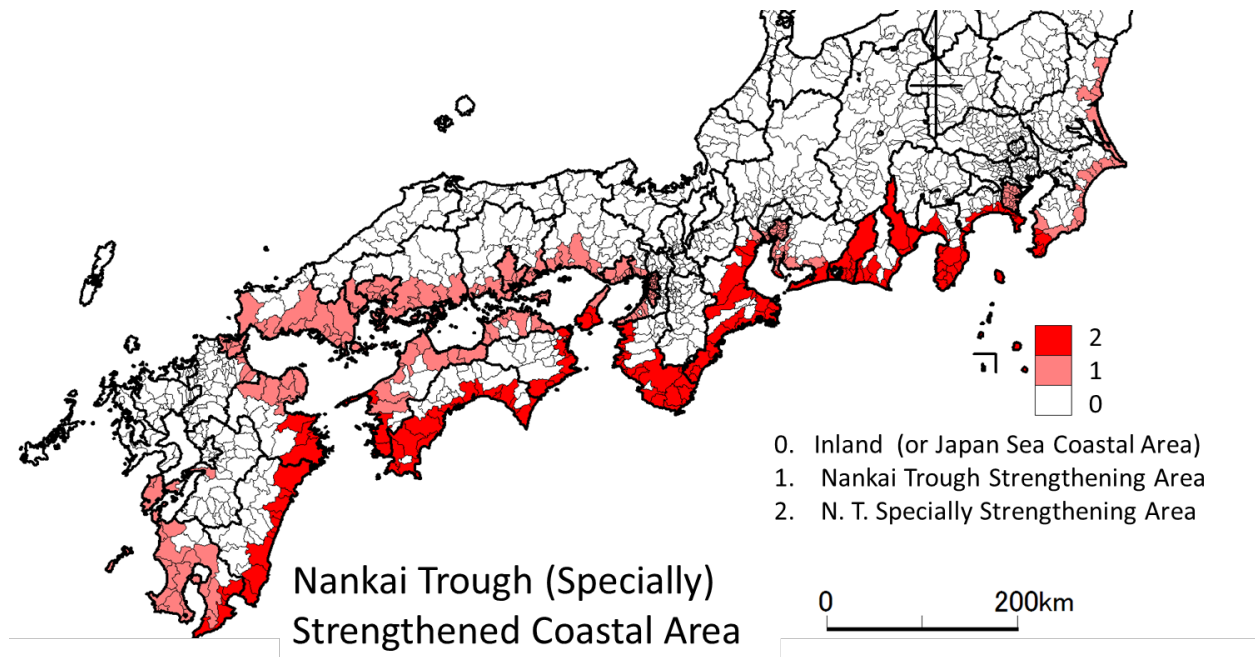


Fig. 21: Nankai Trough (Specially) Strengthened Area (2015)

In addition, despite the severe conditions of tsunami countermeasures, Kochi City, Hamamatsu City, Nobeoka City, and Shizuoka City, all of which have more than 100 public buildings, are designated as TEBs. A more detailed analysis is conducted for a total of seven cities, namely Tokushima, Oita and Miyazaki, where public facilities are designated.

These seven cities are shown in Fig. 22 with slightly larger (triangle) marks. Fig. 23 shows the breakdown of seven cities in the Nankai Trough Earthquake Tsunami Evacuation Countermeasures Specially Strengthening Area where there are many TEBs with public facilities as of 2015. Except for Miyazaki City,



there are more than 35 schools, and except for Kochi City, there are more than 40 public housing. Fig. 24 classifies schools and Fig. 25 classifies details of public housing.

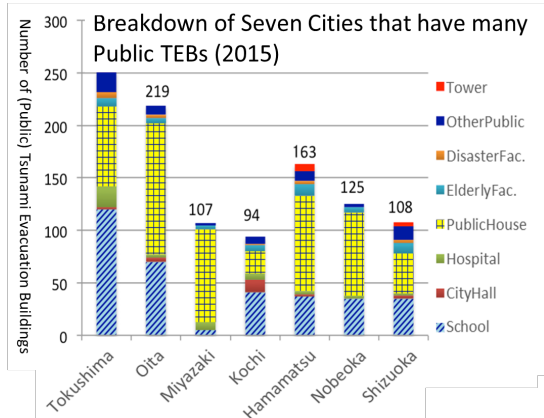
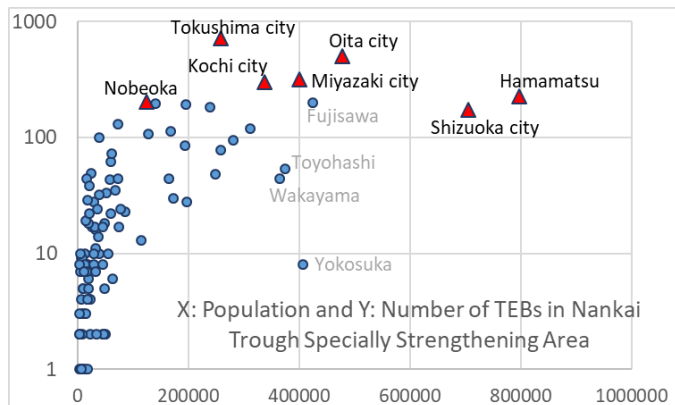


Fig. 22: Use in 7 cities with TEBs as Public ones

Fig. 23: Breakdown of TEBs in Seven Cities

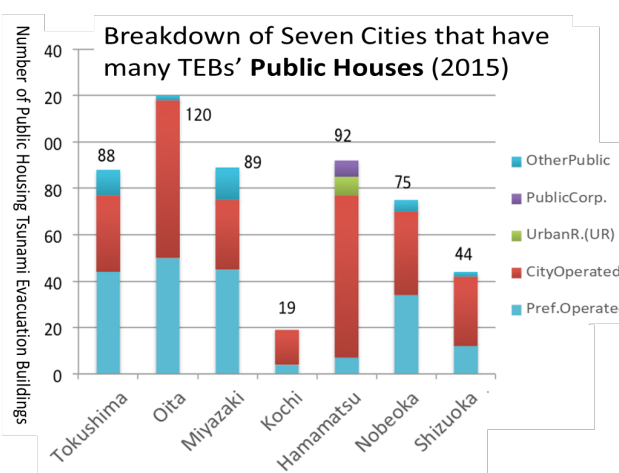
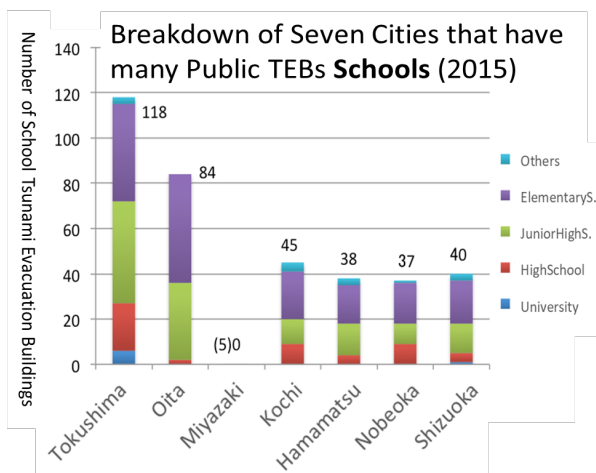


Fig. 24: Breakdown of TEBs for School Use

Fig. 25: Breakdown of TEBs of Public Housing

Fig. 24 and Fig. 25 show that in these seven cities where there is a great risk of tsunami, there are many elementary and junior high schools and public housing in the tsunami inundation area. Others at schools are kindergartens and nursery schools, and others at public housing are dormitories for public employees.

7. Issues of TEB Designation in the Target Area of the Nankai Trough Earthquake

7.1 Issues regarding Designation of TEBs

At the time of the national survey in 2011, about 35% of all TEBs were public facilities, however, because many public facilities have been designated since then, about half of the TEBs are now public. Since TEBs are in principle in the supposed flood area, many public facilities are located in tsunami-prone areas, even though the tsunami inundation assumption was greatly revised between 2012 and 2013 after the Great East Japan Earthquake and Tsunami. Although the number is small compared to schools and public housing, it is also a problem that government offices and hospitals are located in the flooded area.

Furthermore, the term "tsunami evacuation building (TEB)" occupies a large part, however, there are a number of municipalities with various names for facilities with the same purpose. In addition there were some cases that the TEBs could not be seen in the hazard maps or just announced to the public using only municipal papers, not other public information system such as home-pages and SNSs.



7.2 Current Situation and Issues for Evacuation in the Target Area of the Nankai Trough Earthquake

The more serious areas for tsunami countermeasures include the Nankai Trough Earthquake Tsunami Evacuation Countermeasure Strengthening Area and the Specially Strengthening Area. The current situation of the “Nankai Trough Earthquake and Tsunami Evacuation Area” among the municipalities surveyed here is as follows as of 2015. See from Fig. 22 to Fig. 25.

- More than 35 schools are designated in the top 5 cities with the highest absolute TEB numbers,
- Of the top 5 cities, Hamamatsu, Nobeoka and Shizuoka have a lot of public housing including dormitories,
- The designated number of tsunami evacuation towers in Nankoku, Iwata and Hamamatsu is relatively large,
- 21 or more municipalities have designated 40 or more TEBs in the municipalities with the maximum value of the assumed inundation depth of 6-10m. Among them, the cities that are not "Nankai Trough Earthquake Tsunami Evacuation Countermeasures Specially Strengthening Area" are Sakai City, Niigata City, Hakodate City, Kamogawa City and Kamisu City.

The feature here is that the number of designated tsunami evacuation buildings in Numazu City and Yaizu City has decreased since the survey in October 2011, and that in Tokushima City, Oita City and Miyazaki City increased rapidly before 2014. More than 100 schools have been designated in Tokushima City, and more than 100 public houses have been designated in Oita City (Miyazaki City has nearly 100 public houses designated). The current situation is that hospitals are designated in Tokushima City, disaster prevention centers are designated more frequently in Ise City and Yaizu City, and that the rate of designation of public facilities is lower in Numazu City and Hiratsuka City.

Issues concerning the designation of tsunami evacuation buildings in the Nankai Trough Earthquake Tsunami Evacuation Countermeasure Strengthening Area can be pointed out as follows for each target area and city size, particularly for the use of public facilities.

- In government ordinance-designated cities and core cities in the strengthened area, the amount of TEBs was expanded in a short period of time. Schools are undergoing seismic rehabilitation.
- Even in cities with a population of 100,000 or more in the specially strengthened area (less than 500,000 people in many cases), the TEBs were expanded in a short period of time, but many private houses were designated. In that case, consent of the owner and confirmation of the structure are necessary.
- Municipalities with an estimated flood depth of 11m or more in the special strengthened area do not relatively designate public housing. It is good if there is no public housing in the dangerous area.
- Schools are often designated as tsunami evacuation buildings. In this case, it is necessary to keep in mind that it is a temporary / emergency evacuation site, not a so-called evacuation site. Also, unlike public homes, where the outer stairs are always open, it is necessary to use the school building outside the school opening hours and to inform the residents.

8. Conclusions

As a result of analyzing the number of TEBs and their uses, the following facts became clear regarding the designation of TEBs.

1) The number of “Tsunami Evacuation Buildings (TEBs)” has been rapidly increasing after the Great East Japan Earthquake, especially as a countermeasure against the Nankai Trough Earthquake and Tsunami. Compared to the national survey in 2011, as of 2015, the number of buildings has increased nearly three times to over 10,000. In areas, prefectures and municipalities where there is a risk of the Nankai Trough Earthquake and Tsunami, the assumed inundation depth is large and tsunami evacuation buildings are often specified. In the region, Kanto, Chubu, Kinki, Shikoku, the Pacific side of Kyushu, prefectures are Chiba, Kanagawa, Shizuoka, Aichi, Mie, Wakayama, Tokushima, Kochi, Miyazaki.



- 2) In the metropolitan areas such as Osaka and Nagoya, the designated number of TEBs has increased rapidly since the Great East Japan Earthquake, even if the estimated inundation depth was medium (3-5m). Particularly in Kanagawa, Aichi, Osaka, and Hyogo, the number of TEBs designated has increased by a single digit since the June 2011 survey of the government and more than doubled since October 2011.
- 3) In other regions, such as Hokkaido, Hokuriku, China, and Okinawa, there is an area with an increase of more than 10 times. It is smaller than the tsunami target area, and the absolute number of TEBs is small. In Tohoku, affected by the Great East Japan Earthquake, TEBs are rarely specified, and there is no TEB in Iwate Prefecture (it used to exist but is now alongside Nagasaki Prefecture).
- 4) In areas where the estimated tsunami inundation exceeds 20m, designation of TEBs has hardly increased. This may be because there are no corresponding high-rise buildings or hills nearby, but research on tsunami countermeasures in such areas is strongly desired in the future. There are 132 tsunami evacuation towers nationwide as of 2015, all of which are located in areas with large assumed inundation depths.
- 5) Public facilities, which were about one-third in 2011 by application, are now about half. Regarding the use of TEBs, there is not much difference depending on the assumed tsunami inundation depth. Houses and schools, including private rented houses, occupy most of the use of TEBs.

Even after the designation based on the review of the tsunami inundation assumptions and the lessons learned from the Great East Japan Earthquake, it is necessary to make more effective use of the TEB by informing the residents and using software measures such as evacuation drills. If possible, it is necessary to consider long-term measures from the viewpoint of appropriate location. Relationship between other factors (evacuation plans and hazard maps, urban development, etc.) and TEBs should be further investigated.

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(All references are written in Japanese.)