16th World Conference on Earthquake, 16WCEE 2017
Santiago Chile, January 9th to 13th 2017
Paper N°1691
Registration Code: S-X1463203849

Fundamental Study on Evacuation Center Planning in Tsuyama City

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Abstract

The purpose of the present study is, by using the "Tsuyama disaster prevention hazard map" that has been developed in Tsuyama City as basic data, to grasp the distribution state and seating capacity of the evacuation centers which has been specified in the map in the event of a disaster, and to obtain the basic material for planning a proper evacuation center arrangement corresponding to the population distribution of each district in Tsuyama City.

In the evacuation for the whole area of Tsuyama City, it has been revealed that only the indoor space cannot cope with the shortage of the seating capacity, but it can be coped with for the temporary emergency evacuation when including the outdoor space.

When considering each district, there is a district that cannot cope with the emergency evacuation, and there is a district that the seating capacity is not enough even taking the evacuation to the neighboring district into consideration. It has been revealed that 345 people in 1 district cannot respond to the emergency evacuation even when the seismic resistance for the evacuation facilities is not taken into account, and in the case of considering the seismic resistance, 3,477 people in 4 districts cannot perform the emergency evacuation.

As a countermeasure to cope with the emergency evacuation on the whole city basis, it is necessary to consider to use private facilities within the district as emergency evacuation centers without limiting to consider the construction and designation of a new evacuation center, or to use only the public facilities for evacuation facilities. Furthermore, in order to evacuate residents safely, it is required to develop an evacuation plan by taking the landslides and mudslides, blocking of escape routes due to flooding of rivers, and the collapse of the evacuation facility into consideration.

Keywords: Evacuation Center, Seating Capacity, Seismic Resistant, Hazard Map

1. Introduction

1.1 Background of the study

Large-scale natural disasters occur frequently in our country, with examples like the Great Hanshin Earthquake, the Great East Japan Earthquake, the Great Flood of Kii Peninsula in August 2011, and the Kumamoto earthquake in April, 2016. Today, there exists various types of design plans for evacuation facilities in many municipalities, in which most have public facilities like elementary schools as evacuation sites and evacuation zones are designated according to the district of each elementary school. However, in certain communities, the existing evacuation facilities do not have sufficient capacity to provide enough shelter in the face of disasters. Therefore, there is a need to implement evacuation plans that take into consideration the community's population and its characteristics.

1.2 Previous studies

In the study of planning methods of evacuation facilities, Notsuda et al. [1] wrote a report on the optimal planning of evacuation facilities which allows smoother evacuation and the optimal allotment of disaster victims to each evacuation facility when the community population as well as the number of evacuees based on damage estimation can be predicted.

Regarding maintenance of evacuation facilities, Matsumura et al. wrote a report on the ideal environment of evacuation facilities in which elderly persons, disabled persons, and physically-handicapped persons can get through times of disasters in a comfortable manner [2].

1.3 Purpose of study

Tsuyama City is located in the mountainous region of the northern part of Okayama Prefecture (Fig.1). Based on Article 42 of the Disaster Countermeasure Basic Act (1961 Law No. 223), the Tsuyama City Regional Disaster Prevention Plan is created by the Tsuyama City Disaster Prevention Council. The purpose of this plan is to protect the communities of the city and the lives and possessions of its citizens by taking actions to prevent disasters, implementing emergency measures during disasters and disaster recovery efforts. The Tsuyama City Regional Disaster Prevention Plan comprises of "Countermeasures for Flood and Wind Disasters" and "Countermeasures for Earthquake Disasters", with a supplementary "Compilation of Resources". The Tsuyama City Disaster Hazard Map, drawn up based on the Tsuyama City Regional Disaster Prevention Plan, shows the degree of disaster risk in each area of the city. It is created as a soft approach for disaster prevention and serves to support voluntary actions in fortifying disaster preparation measures, victim evacuation and avoiding danger in the event of disasters. It was created in Tsuyama City in January 2007 and has been revised in September 2011 and March 2013 [3].

Fig.1 Okayama Prefecture

The purpose of this study is to provide the basic data for formulating a suitable plan for evacuation facilities in which each facility matches each population distribution of each district in Tsuyama City, by using data from the "Tsuyama City Disaster Hazard Map" to ascertain the distribution and capacity of each evacuation facility designated.

2. Investigation method

2.1 Tsuyama City disaster prevention Hazard Map

The Tsuyama City Disaster Hazard Map consists of three parts. Firstly, the basic information section contains a list of the designated evacuation facilities, emergency contact information, a list of facilities related to disaster prevention, URLs of sites with disaster prevention information, and channels of communication of information. Next, there is a map showing the city divided into eight regions and locations of evacuation centers, places with risk of mudslides, steep slopes with risk of collapse, and places with risk of landslides are marked on the map. The third part is a soft measure, i.e., guidelines on what to do in the event of an emergency or disaster and disaster preparedness in the event of flood, wind, or earthquakes.

Information on all designated evacuation facilities (149 facilities) are recorded according to each of the 28 districts of all eight regions (Fig.2, Fig.3), and include information like the names, phone numbers, evacuation capacities (outdoor and indoor), and indications if they contain structures built before 1981, flood history and possibility of landslides.

Fig.2 The eight regions in Tsuyama City

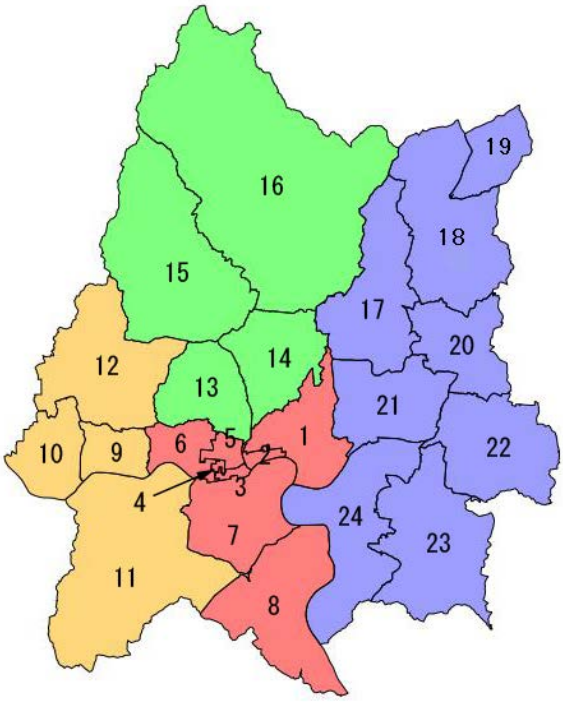

Fig.3 The districts until No.24

2.2 Investigation method

This study conducts an evaluation on the advisability of this evacuation plan by using data of the designated evacuation facilities and the newest data on the population distribution of each district dated October 1st, 2010. In this study, outdoor capacities of each facility are also taken into account when calculating capacities during an emergency evacuation. In addition, by taking into consideration the possible damages of the evacuation centers during the disaster, as facilities with structures built before 1981 are not earthquake resistant, indoor capacities of these facilities are excluded. The same is applied to facilities which have a flood history and those at risk of landslides. Table 1 show the populations, number of evacuation centers, outdoor and indoor capacities of each evacuation center with and without taking into consideration damages caused by the disaster as well as the excess or deficiency of the each capacity.

Table.1 Specifications and seating capacity of each district

Region	District	Population	Shelter	When not taking into account damages of evacuation centers				When taking into account damages of evacuation centers			
				Seating capacity		Excess or deficiency of the seating capacity		Seating capacity		Excess or deficiency of the seating capacity	
				Indoor	Outdoor	Indoor only	Indoor + Outdoor	Indoor	Outdoor	Indoor only	Indoor + Outdoor
Central	1. Higashi-Tsuyama	8,513	9	3,060	15,750	-5,453	10,297	2,830	15,750	-5,683	10,067
	2. Jyoto	1,338	2	950	6,260	-388	5,872	950	6,260	-388	5,872
	3. Jyonan	767	3	1,710	0	943	943	1,610	0	843	843
	4. Chuo	512	2	1,000	3,730	488	4,218	1,000	3,730	488	4,218
	5. Jyohoku	2,127	3	1,310	3,470	-817	2,653	540	3,470	-1,587	1,883
	6. Kakujyo・Jyosai	6,246	7	3,380	12,350	-2,866	9,484	3,210	12,350	-3,036	9,314
	7. Fukuoka	3,309	7	1,210	4,550	-2,099	2,451	120	0	-3,189	-3,189
	8. Fukunan	395	1	50	0	-345	-345	0	0	-395	-395
Western	9. Ninomiya	2,610	4	820	2,830	-1,790	1,040	760	2,830	-1,850	980
	10. Innosho	3,374	8	710	3,180	-2,664	516	620	3,180	-2,754	426
	11. Sarayama	6,669	6	950	8,490	-5,719	2,771	0	6,660	-6,669	-9
	12. Tanomura	1,740	4	220	310	-1,520	-1,210	140	310	-1,600	-1,290
Northern	13. Nishi-Tomada	11,846	9	4,860	18,700	-6,986	11,714	3,870	18,700	-7,976	10,724
	14. Higashi-Tomada	8,177	6	2,860	37,060	-5,317	31,743	2,590	37,060	-5,587	31,473
	15. Ichinomiya	5,434	3	800	4,440	-4,634	-194	680	4,440	-4,754	-314
	16. Takada	2,237	4	510	2,020	-1,727	293	490	2,020	-1,747	273
Eastern	17. Takakura	1,783	3	540	1,610	-1,243	367	520	1,610	-1,263	347
	18. Kanba	904	2	510	1,460	-394	1,066	470	1,460	-434	1,026
	19. Takio	879	2	60	0	-819	-819	0	0	-879	-879
	20. Seimei	1,775	5	700	4,260	-1,075	3,185	670	4,260	-1,105	3,155
	21. Takano	7,413	2	1,080	2,460	-6,333	-3,873	1,080	2,460	-6,333	-3,873
	22. Hirono	1,647	2	370	1,670	-1,277	393	340	1,670	-1,307	363
	23. Ohsaki	2,548	4	770	2,480	-1,778	702	750	2,480	-1,798	682
	24. Kawanobe	5,531	4	1,030	1,380	-4,501	-3,121	920	1,380	-4,611	-3,231
Kamo	25. Kamo	4,755	7	1,830	14,990	-2,925	12,065	1,570	14,990	-3,185	11,805
Aba	26. Aba	576	5	700	4,490	124	4,614	190	2,830	-386	2,444
Shoboku	27. Shoboku	6,717	12	2,820	25,420	-3,897	21,523	2,580	25,420	-4,137	21,283
Kume	28. Kume	6,966	23	2,650	19,120	-4,316	14,804	1,590	7,540	-5,376	2,164
Tsuyama entire		106,788	149	37,460	202,480	-69,328	133,152	30,090	182,860	-76,698	106,162

3 Total capacity of evacuation centers

While examining the possible number of evacuees in each evacuation center, evacuation for a certain period of time between victim evacuation and moving the victim into temporary housing facilities is considered as evacuation to indoor facilities, and temporary emergency evacuation is considered as evacuation that includes outdoor facilities. The following analysis was done.

3.1 Overall evacuation capacity of Tsuyama City

When not taking into account damages of evacuation centers caused by the disaster, with a combined capacity of 37,460 evacuees, for 106,788 inhabitants of Tsuyama City, 65.0% of the population i.e., 69,328 people will not be able to be evacuated. If the outdoor capacity is included, the total capacity for evacuees becomes 239,940, so full evacuation is possible in the case of an emergency evacuation (Table 1).

Among the 149 evacuation centers, 42 centers are not earthquake resistant, 8 have flood history, and 7 are at risk of landslides, making a total of 57 centers (in which 3 have overlapping criteria). When taking into account damages of evacuation centers caused by the disaster, for 106,788 inhabitants of Tsuyama City, with a combined capacity of 30,090 evacuees, 71.8% of the population i.e., 76,698 people will not be able to be evacuated. If the outdoor capacity is included, the total capacity for evacuees become 212,950 so full evacuation is possible in the case of an emergency evacuation (Table 1).

3.2 Capacities according to districts

When not taking into account damages of evacuation centers caused by the disaster, only three districts have sufficient capacities for evacuation to indoor facilities. These are the Jyonan, Chuo, Aba districts. The other areas did not have enough capacities (Table 1).

If outdoor capacity is included, six districts were found to have insufficient capacities: Fukunan (345 lacking), Tanomura (1210 lacking), Ichinomiya (194 lacking), Takio (819 lacking), Takano (3873 lacking), and Kawanabe (3121 lacking). In the event of an emergency disaster, 9,562 inhabitants will not be able to be evacuated (Table 1).

When taking into account damages of evacuation centers caused by the disaster, all districts except for the Jyonan and Chuo districts do not have sufficient capacities. If outdoor capacity is included, eight districts were found to have insufficient capacities: Fukuoka (3,189 lacking), Fukunan (395 lacking), Sarayama (9 lacking), Tanomura (1290 lacking), Ichinomiya (314 lacking), Takio (879 lacking), Takano (3873 lacking), and Kawanobe (3,231 lacking). In the event of an emergency disaster, 12.3% of the population of Tsuyama City, 13,180 people, will not be able to be evacuated (Table 1).

3.3 Evacuation to adjacent districts

For the eight districts shown to have insufficient capacities as mentioned in 3.2, we examined the advisability of evacuation to adjacent districts in the event of emergency evacuation. The results are shown in Tables 2 and 3. In this case, due to landslide disasters and river flooding, evacuation processes to adjacent districts which require the crossing of mountains and bridges have been excluded. The capacity shown in the table is calculated by deducting the number of evacuees coming from an adjacent district from the combined indoor and outdoor capacity of the district.

When not taking into account damages of evacuation centers caused by the disaster (Table 2, Fig 4), evacuation from Fukunan (395 lacking) to an adjacent district is not possible due to its geographical location surrounded by mountains and rivers.

When taking into account damages of evacuation centers caused by the disaster (Table 3, Fig 5), in addition to Fukunan, evacuation from Fukuoka (3189 lacking) or Sarayama (9 lacking) to an adjacent district is not possible because of the lack of adjacent districts with extra capacities. When not taking into account damages of the evacuation center caused by the disaster, Fukuoka has an extra capacity of 2,451 people, and is therefore able to accept evacuees from Sarayama. However, these three districts are facing the right bank of the Yoshii River. In Fukuoka, there is an evacuation center with flood history (2,700 lacking), and in combination with non-earthquake resistant evacuation centers and centers at risk of landslides, in a worst-case scenario, 4 evacuation centers with a combined capacity of 5,460 people will be lost. Fukuoka will have insufficient capacity for 3,189 people, and thus will not be able to take in extra evacuees coming from Sarayama.

For evacuation from Tanomura to Ninomiya and Innosho due to the capacity shortage of 116 people, evacuation is possible when not taking into account damages of evacuation centers caused by the disaster. However, among 12 evacuation centers in Ninomiya and Innosho, 5 are non-earthquake resistant. This results in capacity shortage of indoor evacuation for 150 people, and thus, these two districts will not be able to accept evacuees from Tanomura.

Based on the above, it is found that when taking into account damages of evacuation centers caused by the disaster, 3.3% of the population of Tsuyama City i.e., 3,477 people cannot be evacuated, even when emergency evacuation to adjacent districts is implemented.

Table.2 When not taking into account damages of evacuation centers

The advisability of evacuation to adjacent districts			Excess or deficiency
8 Fukunan	→	There is no district for emergency evacuation.	-345
12 Tanomura	→	9 Ninomiya + 10 Innosho	346
15 Ichinomiya	→	14 Higashi-Tomada	31,549
19 Takio	→	18 Kanba	247
21 Takano	→	20 Seimei + 22 Hirono + 1 Higashi-Tsuyama	10,002
24 kawanobe	→	23 Ohsaki + 1 Higashi-Tsuyama	7,878

Table.3 When taking into account damages of evacuation centers

The advisability of evacuation to adjacent districts			Excess or deficiency
7 Fukuoka	→	There is no district can afford to capacity.	-3,189
8 Fukunan	→	There is no district for emergency evacuation.	-395
11 Sarayama	→	There is no district can afford to capacity.	-9
12 Tanomura	→	9 Ninomiya + 10 Innosho	116
15 Ichinomiya	→	14 Higashi-Tomada	31,159
19 Takio	→	18 Kanba	147
21 Takano	→	20 Seimei + 22 Hirono + 1 Higashi-Tsuyama	9,712
24 Kawanobe	→	23 Ohsaki + 1 Higashi-Tsuyama	7,518

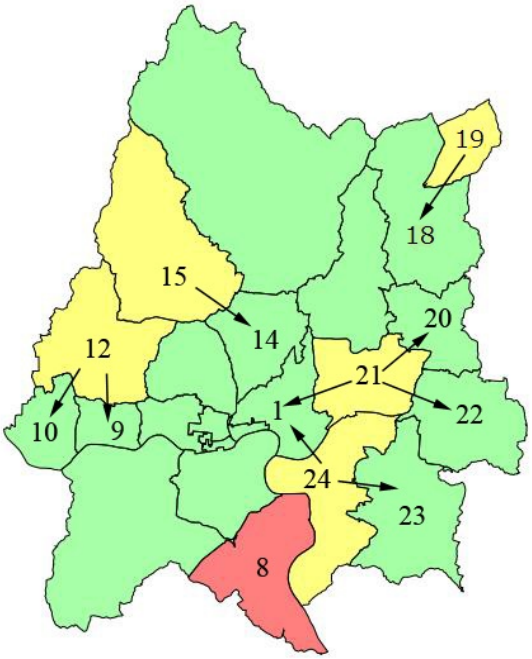

Fig.4 When not taking into account damages of evacuation centers

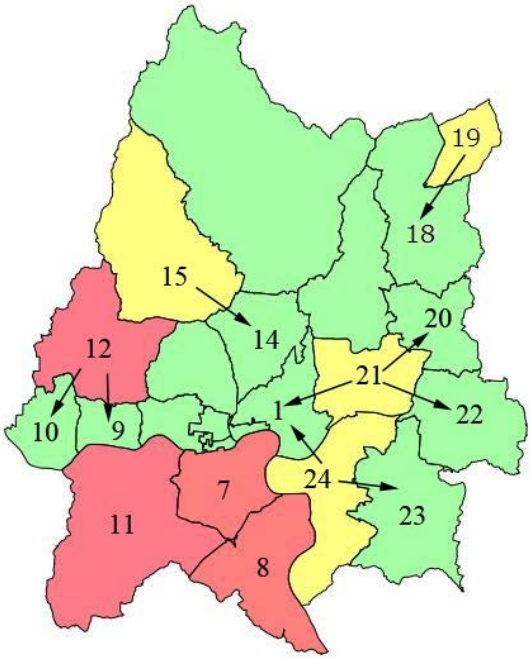

Fig.5 When taking into account damages of evacuation centers

4. Conclusion

This study was done in order to contribute to the formulation of an evacuation facility plan that matches the population distribution of each district in Tsuyama City, based on the data in the "Tsuyama City Disaster Hazard Map".

1) Among the 149 designated evacuation centers, 54 have risks of being damaged through collapse, flooding, or landslides in the event of an earthquake. Therefore, urgent attention to address this issue is advisable.

2) When taking into account damages of evacuation centers caused by the disaster, in a worst-case scenario, evacuation in all regions of Tsuyama City is possible if outdoor capacity is included. However, 65.0% of the population of the city is not evacuated to indoor facilities, so many victims will have no choice but to remain outdoors for a certain period of time until they are moved to temporary housing facilities.

3) When examining by district, when taking into account damages of evacuation centers caused by the disaster, in a worst-case scenario, it is found that full emergency evacuation is not possible in eight districts. Even when evacuation to adjacent districts is implemented, there are still insufficient capacities in four districts. The study has also showed that only two districts have sufficient evacuation for a certain period of time, and there is not enough capacity of indoor evacuation centers.

4) As an emergency evacuation measure, the city must consider the construction or designation of new evacuation centers or designate private facilities in the districts as emergency evacuation centers without limiting the evacuation centers to public facilities.

Furthermore, in order for all disaster victims to evacuate safely in the event of a disaster, we must formulate an evacuation plan that takes into consideration the blockade of evacuation routes and damage of facilities caused by landslides, mudslides, or river flooding.

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