Exploring key issues related to tsunami shelter in Padang city – Indonesia

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Abstract. Padang is a city on the coast of Sumatra island in the province of West Sumatra that has the potential to be threatened from a tsunami originating from the Mentawai megathrust. Various attempts have been made by the Padang City Government to anticipate casualties if a tsunami really occurs. One such effort is in the form of building shelter or TES (Temporary Evacuation Sites). Unfortunately, until now the data on the capacity of existing shelter and the number of shelter needed have not been found. In addition, the maintenance of existing shelters has the potential to become a burden on the Padang city government budget. The Mayor of Padang once complained about the need for the budget to build and maintain the shelter building so that it could function properly when needed. Therefore it is necessary to conduct a study regarding the optimal amount of shelter and how to optimize its function. Determination of the optimal number of shelter begins by identifying factors that influence the determination of the location of the shelter through questionnaires and interviews. This study also examines the alternative use of shelter and maintenance techniques so that the constructed shelter can be effective and efficient according to its function but still economical or not a burden on the government budget.

1 Introduction

Padang is located in the West Sumatra province of the island of Sumatra. Subduction of the Indian-Australian plate beneath the continental Eurasian (Sundaland) plate at a rate 7 cm/year with N20 azimuth, down the Sunda Trench (Minster and Jordan, 1978; De-Mets et al., 1990). Oblique subduction at about 45 has resulted in two significant faults that are parallel to and lie between the trench and volcanic arc. The vertical Sumatran (Semangko) Fault marks the boundary between the Eurasian (Sundaland) plate and the majority of the volcanic arc to the northeast with a forearc basin to the southwest, while the Mentawai Fault (Kemal B.M., 1993) separates the forearc basin from a forearc accretionary ridge complex further southwest. The entire forearc sliver between the trench and the Sumatran Fault is decoupled and moves northwestward.

Some areas of the city of Padang in the form of a plain with a slight slope to the east. But in some areas that are almost flat, there are more than half of the city's population. With a population of 914,968 (BPS, 2016), 508,804 of them are in the tsunami red zone (BNPB, 2010).Padang City has a population of 914.968 (BPS, 2016). 508,804 of them inhabit the tsunami red zone (BNPB, 2010). The tsunami red zone is a zone that is predicted to be hit by the tsunami. With the large number of people inhabiting zones that have the potential to be threatened by the tsunami, the government needs to think of efforts to save these threatened populations, for example by providing facilities for vertical evacuation. Vertical evacuation is believed to be a preferred mitigation, because the effective time available to do so is very little, which is 17 minutes (Kemal et al, 2017). But until now in the city of Padang only four official buildings were built as TES (Temporary Evacuation Sites).

The objective of this study is to identify and explore key issues related tsunami shelter in Padang.

2 Literature Review

2.1 Tectonics Setting of Sumatra

Sumatra island where the city of Padang located is part of the Eurasian tectonic plate which collides with the Indo-Australian plate. As a result of this collision, the Indo-Australian oceanic plate goes down Sumatra.

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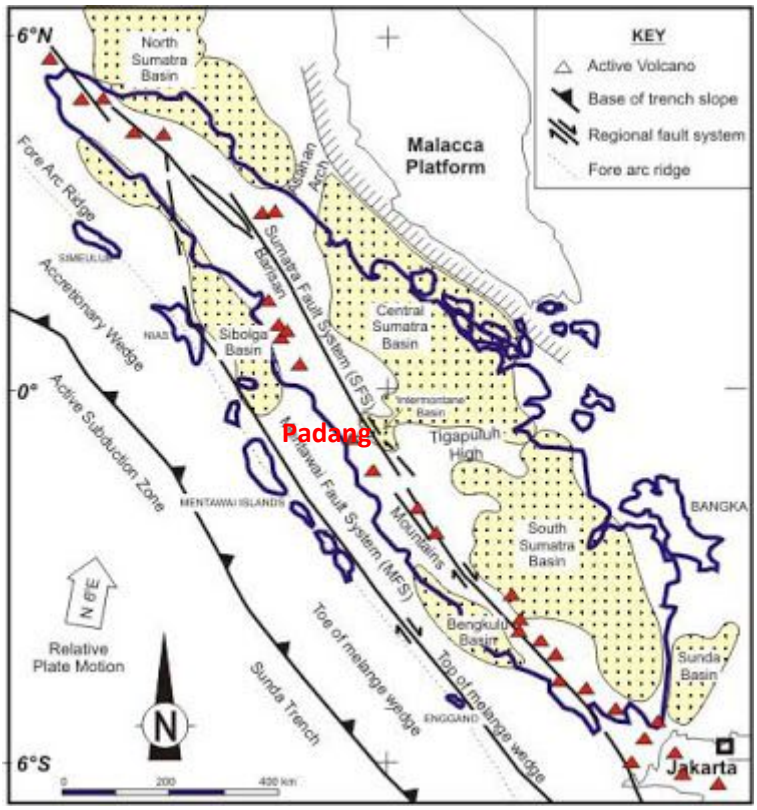

Fig. 1. Regional tectonic setting map of Sumatra Island (modified from Bennet et al., 1981)

The tectonic conditions in Sumatra then led to the emergence of megathrust in the form of accretionary prisms that emerged as non-volcanic islands in front of Sumatra such as Simeulue, Nias, Siberut, Sipora, Pagai, Enggano and others. This Megathrust later became the source of a powerful earthquake above 7.0. These earthquakes in the megathrust area usually have very shallow depths. Because of that it has the potential to cause a tsunami. Some powerful earthquakes that cause tsunamis are shown in the following Fig. (Fig. 2). In Fig 2 it can be seen that there are two segments in the Mentawai archipelago, namely the Siberut and Sipora-Pagai segments. In the Siberut segment in 1797 there was an earthquake measuring 8.7-8.9 magnitude. Then in 1833 in the Sipora-Pagai segment there was a very strong earthquake measuring 8.9 magnitude. Both the earthquake in the Siberut segment and the Sipora-Pagai segment caused a tsunami (Borrero et al., 2009). In the Sipora-Pagai segment, a very strong earthquake was repeated successively on September 12, 2007 with a strength of 8.4 magnitude and on September 13, 2007 with a strength of 7.9 magnitude. Both earthquakes in the 2007 Sipora Pagai segment did not cause a large tsunami, except only a small tsunami (Borrero et al., 2009). Fujii & Satake (2008) stated that the tsunami height was approximately 1 meter in the city of Padang. While the tsunami that occurred in this segment in 1833, also in the Siberut segment in 1797 was large (Natawidjaja et al., 2006). 1797 caused an earthquake measuring 8.7 - 8.9 magnitude has not yet repeated a return period, except for the earthquake that occurred on 30 September 2009 with a strength of 7.6 magnitude (USGS, 2009).

With this magnitude 7.6 earthquake occurring, many experts said that the stored energy was still two-thirds more in this segment, which could cause an earthquake of magnitude 8.6 or even more (McCloskey, 2010).

1.1. TES (Temporary Evacuation Site): tsunami shelter

TES is a building that can be used to vertically evacuate multi-storey buildings. The high inundation of sea water that rises to land in the event of a tsunami according to Latif's prediction (2018) is 4.7 meters.

Meanwhile, megathrust in the Siberut segment in Methodology In order to collect data for this study, an FGD (Focus Group Discussion) has been conducted in Pusdalops UPT BNPB Padang, attended by experts and activists in disaster reduction in Padang and West Sumatra. In addition,

surveys were also carried out to temporary evacuation sites, namely four special evacuation sites built by the government (BNPB)
This FGD invited competent speakers in the field of disaster, especially the tsunami and BPBD Sumatra Barat (Badan Penanggulangan Bencana Daerah-West Sumatra Regional Disaster Management Agency) institutions as competent and responsible for disaster risk reduction efforts, including facilitating the construction of TES.

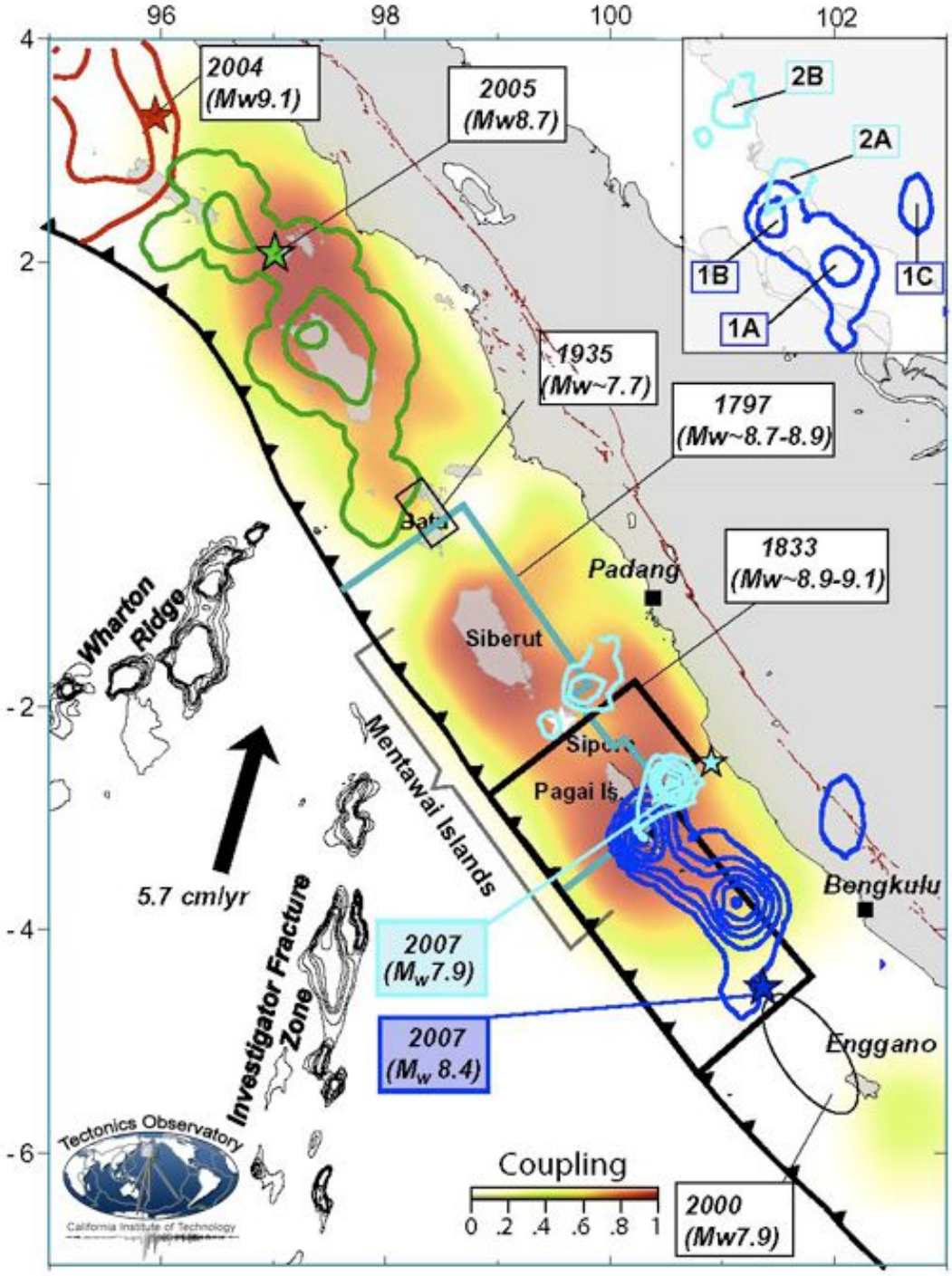

Fig. 2. Some records of massive earthquake events originating in megathrust in front of Sumatra island in the Simeulue, Nias, Mentawai and Enggano segments.
Section 1.01 (http://www.tectonics.caltech.edu/images/sumatra/locked_zones.jpg)

3. Result

3.1. TES in Padang

Aware of the threats that come from the Siberut segment megathrust, the Padang city government has made various mitigation efforts. One such effort is to design and realize the establishment of TES (Temporary Evacuation Site). TES is a vertical evacuation place in the tsunami red zone. At present the government has built four TES, namely in the Ulak Karang, Komplek Jondul Kelurahan Parupuk, Lubuk Buaya and Shelter Darussalam Kelurahan Tabing areas.

As for official TES: it has a considerable capacity. Then it is also equipped with public kitchen facilities, bathroom and toilet.
In addition to these four official TES units, there are also a number of government buildings that has also a function as TES. These buildings were built after a strong earthquake 29-09-2009. In addition, there are also a number of private-owned high-rise buildings which are expected to function as evacuation sites from the tsunami. These buildings are multi-storey where the height of the floor is at least 10 meters above sea level. The following table is a government-owned and private building that have dual function as an evacuation site

Table 1. Government and private buildings that also function as TES (BPBD Sumbar, 2018)

No.	Name of Shelter	Capacity	Distance from the beach (m)	Address
1	AMIK Indonesia	2000	1,150	Jl. Khatib Sulaiman
2	Axana Hotel	2000	725	Jl. Bundo Kandung
3	Bank Nagari Pemuda	3000	300	Jl. Pemuda
4	Bank Negara Indonesia (BNI)	3000	750	Jl. Kampung Dobi
5	Bappeda Prov. Sumbar	2000	1,250	Jl. Khatib Sulaiman
6	Basko Hotel & Plaza	2000	750	Jl. Prof. Hamka
7	Bukit di Air Manis	3000	675	Air Manis-Padang Selatan
8	Bukit di Lantamal II	2000	2,200	Lantamal II-Padang Selatan
9	Bukit di Sungai Pisang	2000	990	Sungai Pisang-Padang Selatan
10	Bukit Gunung Padang	3000	970	Samping Muaro-Padang
11	Bukit Gunung Pangilun (PDAM)	2000	2,075	Gunung Pangilun
12	Bukit Sungai Gaung	2000	475	Sungai Gaung-Padang Selatan
13	Bumi Minang Hotel	2000	640	Jl. Gereja
14	Damar Plaza	2000	380	Jl. Damar
15	Ditjen Perbendaharaan Sumbar	2000	1,650	Jl. Khatib Sulaiman
16	DPRD Prov. Sumbar	2000	920	Jl. Khatib Sulaiman
17	Escape Building Kantor Gubernur	5000	1,000	Jl. Jendral Sudirman
18	Fakultas Ilmu Pendidikan UNP	2000	650	Jl. Prof. Hamka
19	Fakultas Olahraga UNP	2000	400	Jl. Prof. Hamka
20	Gedung Asuransi Jasa Raharja	2000	1,220	Jl. Ujung Gurun
21	Gedung BPK	2000	1,270	Jl. Khatib Sulaiman
22	Gedung Bank Indonesia	1000	1,250	
23	Gedung Daihatsu & ACC Finance	3000	960	Jl. Khatib Sulaiman
24	Gedung Dinas Peternakan	1000	1,350	Jl. Rasuna Said
25	Gedung Dinas PrasJal TR & Pemukiman	5000	1,500	Jl. Taman Siswa no.1
26	Gedung Grand Zuri Hotel	3000	1,280	Jl. MH. Thamrin
27	Gedung Mercure Hotel	3000	225	Jl. Purus IV
28	Gedung PSDA Prov. Sumbar	2500	980	Jl. S. Parman Ulak Karang
29	Gedung Rusunawa	3000	120	Jl. Purus IV
30	Gedung Sekolah al-Azhar 32	3000	1,100	Jl. Khatib Sulaiman
31	Gedung Univ. Bung Hatta	2000	275	Ulak Karang
32	HW Hotel	4000	260	Jl. Hayam Wuruk
33	Ibis Hotel	3000	1,450	Jl. Taman Siswa
34	Ina Muara Hotel	4000	450	Jl. Gereja
35	Jl Bungus Lb. Kilangan	2000		
36	Kuburan Cina	2000	740	Bungus
37	Mariani Internasional Hotel	2000	585	Jl. Gereja
38	Mesjid Darussalam	5000	925	Kel. Bungo Pasang
39	Masjid Nurul Iman Padang	3000	1000	Jl. MH. Thamrin

40	Masjid Muhajirin	4000	620	Kompl. Pasir Putih Kel. Bungo Pasang
41	Masjid Nurul Haq	4000	310	Kompl. Kondul Parupuk Tabing
42	Masjid Taqwa Muhammadiyah	3000	835	Pasar Raya
43	Masjid Raya Sumbar	4000	1,400	Jl. Khatib Sulaiman
44	Pangeran Beach Hotel	4000	120	Jl. Juanda
45	Pangeran City Hotel	3000	715	Jl. Kampung Dobi
46	Pasar Inpres	3000	1,030	Pasar Raya
47	Pasca Sarjana UNP	2000	580	Jl. Prof. Hamka
48	Perpustakaan UNP	2000	540	Jl. Prof. Hamka
49	Plaza Andalas	2500	420	Jl. Pemuda
50	Gedung Mapolda	4000	1,090	Jl. Padang Pasir
51	PT AMP	4000	890	Parupuk Tabing
52	PT Suka Fajar	2500	410	Jl. Veteran
53	Rocky Hotel	2000	860	Jl. Permindo
54	RS M. Jamil	4000	1,800	Jl. Perintis Kemerdekaan
55	Rumah Sakit Yos Sudarso	2000	1,300	Jl. Situjuh
56	SD Agnes	2000	570	Jl. Bandar Gereja
57	SD Damar	2000	815	Jl. Padang Pasir
58	SD Setia	2000	810	Air Tawar Barat
59	SDN 15 Lolong	2000	70	Belakang Taman Makam Pahlawan
60	SDN 23/24 Ujung Gurun	3000	360	Jl. Veteran
61	SDN 25	2000	320	Air Tawar Selatan
62	SMAN 1	3000	600	Jl. Belanti Raya no. 11
63	SMAN 3	3000	1,700	Gunung Pangilun
64	SMKN 5	3000	280	Jl. Beringin No. 4
65	SMPN 13	2000	825	Parupuk Tabing
66	SMPN 25	3000	990	Jl. Beringin Belanti Timur
67	SMPN 3	2000	760	Jl. Pulau Karam
68	SMPN 4	2000	900	Jl. Pulau Karam
69	SMPN 7	2000	300	Jl. S. Parman Lolong
70	Gedung Telkom I. Bonjol	2000	1,200	Jl. Bgd. Azis Chan
71	Univ. Ekasakti	4000	560	Jl. Bandar Purus
72	Universitas Muhammadiyah	3000	380	Parupuk Tabing
73	Universitas Taman Siswa	2000	1,720	Jl. Taman Siswa
74	Villa Hadis	2000	1,020	Jl. Khatib Sulaiman
	Total	**194.500**		

All buildings mentioned in the table above have not been verified as being feasible in their strength against earthquakes that precede the tsunami. It can be reduced after verification. These buildings are not specifically planned for evacuation sites. Therefore the government must make a Memorandum of Understanding (MoU) with building owners. If a MoU has been made, then special access will be built such as an external ladder that allows people to evacuate to the building, both on weekdays and outside working hours and holidays.

3.2. Key Issues of TES needs in the city of Padang

There has been no research that can determine the number of official TES needed by people who are potentially affected by the tsunami in the red zone. Research on this number seems to be necessary, related to the estimated number of people who need it. Previously, people who were prioritized for vertical evacuation using TES were needed. Priorities for using TES are elderly parents, pregnant women, children and people with special needs. The rest is assumed to be able to evacuate horizontally to the east to a minimum altitude of 10 meters above sea level. In the city of Padang there is a special sign made on the highway, which is a sign that says a safe border from the tsunami.

Based on the table above, the capacity of multi-storey buildings that can be used for communities threatened by a tsunami is sufficient. Because, part of the threatened community in the tsunami red zone is expected to choose, or it is recommended to choose horizontal evacuation. But the amount is not enough if the Padang city government has not yet entered into a MoU with building owners. Then the amount can be insufficient if after assessment of building construction there are buildings that do not meet earthquake-safe building regulations (building code). Therefore, it can be ascertained that a new evacuation building is needed, which meets the building standards for earthquake safety and tsunami safety, and can function optimally with various functions or uses. Because, in some urban areas there

are no multilevel buildings either government or private in the red zone of the tsunami.

3.3. Current condition of TES

Of the four existing (official) TES, it has not been used as expected. In general, all of these shelters have not been properly managed. Of all the assessments given by FGD participants, they can be grouped into five categories as follows.

1. Benefits: This TES has not provided maximum benefits to the community. As stated by Martios Alius, the person in charge of the TES in Ulak Karang Padang; "This TES is just waiting for the tsunami to come. It does not function for social activities. This happened, because before the construction, the community was not invited to discuss about the management plan and utilization of the TES. While the cost of this TES is expensive". Januar, an activist from the KSB (Disaster Preparedness Committee) said: "TES is used for useful activities such as sports, but often also used by some young people to date. So, the utilization is not maximal ". Yenni Yuliza also stated: "Existing TES can be used as a village office so that it can provide maximum benefits".
2. Maintenance of buildings: It has not gone well.
   Dr. Eva Rita stated as follows: *"There are about 30% of the people who do not know the TES, the buildings they see every day. This is surprising. There are also some people who feel they don't need TES. They were quite resigned to facing the tsunami. Then, the Chairperson of the RT (Neighbourhood leader) and Chair of the RW (Commune leader) as the local leader in the TES location is located, it should have a maximum function in the use and management of TES, both for daily use and when needed at night evacuation".*
   Syafrimet, a disaster risk reduction activist from Jemari Sakato (NGO) stated that the community's understanding of the threat of disaster was still lacking. He said: *"It is necessary to continue educating the public so that people are aware of the disaster. Furthermore, people who are aware of the disaster will later be aware of the need for a TES and can participate in maintaining it".*
   Meanwhile Edi Hasymi, the head of the Padang BPBD implementation admitted that the treatment of TES was not maximized, because of the four TES buildings, only two had been handed over from BNPB to the Padang city government. As stated: *"TES maintenance has not been fully carried out because not all TES buildings have been handed over to us. Two buildings that have been handed over have been formed by the management ".*
3. Feasibility of TES:
   The feasibility of TES as a place for evacuation from the tsunami is still considered less feasible. Because, the facilities available in the TES building are still not as they should be. Patra stated as follows: *"In a TES there must be a logistics warehouse to store only food, drinks or other important necessities needed by the people who take refuge there. In addition, there must be a KSB in each TES. Whereas currently KSB is only available at the village level. TES buildings also should not be too close to the beach to avoid grinding the foundation of the building by a tsunami. In addition, schools or communities near a TES building must have plan B if the TES turns out to be collapsed by an earthquake".* Yenni Yuliza also stated: *"Access to TES must be open to the public".*
4. Capacity:
   The capacity of TES and multi-storey buildings that can be used as evacuation sites from the tsunami is not sufficient. To calculate the TES requirements related to its capacity, it needs to be done carefully, as stated among others by Eliyusman: "It is necessary to count the population in various circumstances, for example the number of residents day and night, and between workdays and week-end. This is all related to the shelter capacity needed ".
5. Responsible officer:
   Although in the two TESs that have been formally handed over, the management has been formed, but it turns out that responsibility has not yet proceeded as it should. The proof is that there are TESs that are used by some young people to carry out activities that are not useful, such as dating.

4. Conclusion

1. Padang has a large population threatened by a tsunami.
2. Although a portion of the population in the tsunami red zone will evacuate horizontally away from the coast, walking towards the east, but the capacity of multi-storey buildings in the red zone is not comparable to the population requiring vertical evacuation. Especially when compared to official TES
3. From official TES, utilization has not been maximized. From the FGD and the investigation at the TES location, it was found that the TES that only functioned as an evacuation site looked like less useful
4. With the plan to continue to realize the TES in accordance with the amount needed, then in the future TES must function double or multiple

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