TSUNAMI VULNERABILITY OF CRITICAL INFRASTRUCTURES IN THE CITY OF PADANG, WEST SUMATERA

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Abstract

Based on historical records and latest studies on seismic activities in Sumatra mega thrust, the city of Padang is predicted to experience earthquake M_w.8 followed by tsunami in coming decades. Many efforts have been made to mitigate the impact of earthquake and tsunami such as: setting up early warning system, arising public awareness through education, and building shelters and tsunami evacuation routes. However, none of the efforts have been directed to the significance role of critical infrastructures. Having learnt from the 2004 Aceh tsunami, the existence of critical infrastructures played a key role in the processes of aids distribution, rehabilitation and reconstruction after the disaster. Therefore, the objective of this study is to assess tsunami vulnerability of 198 critical infrastructures in Padang using Papathoma Tsunami Vulnerability Assessment (PTVA-3) method by considering hydrodynamics, building characteristics, functionality, and physical environment. The analysis shows that more than 50% of critical infrastructure in Padang is highly vulnerable.

Keywords: tsunami, critical infrastructures, vulnerability, Padang

1. BACKGROUND

Indonesia's territory is one of the earthquake and tsunami prone areas. Latif *et al.* (2000) stated that since the year 1600 to 1999 there has been 105 tsunami occurrences in Indonesia, where 90% of the total events triggered by the earthquakes while the rests are due to volcanic eruptions and submarine landslides. West Sumatera Province, Indonesia, particularly the city of Padang has been considered as one of the most vulnerable city to large earthquake and tsunami in the near future (Natawidjaya *et al.*, 2006; Wisemann et al., 2011; Huang *et al.*, 2009). The potential earthquakes in this region may occur along the Sumatera Mega thrust where seismic gaps have been identified offshore the Mentawai Islands chain. Moreover, Paleo-tsunami records also show evidence of a super-cycle large earthquake occurrences every ~200 years where the last big ones occurred in 1789 and 1833 (Sieh *et al*., 2008)).

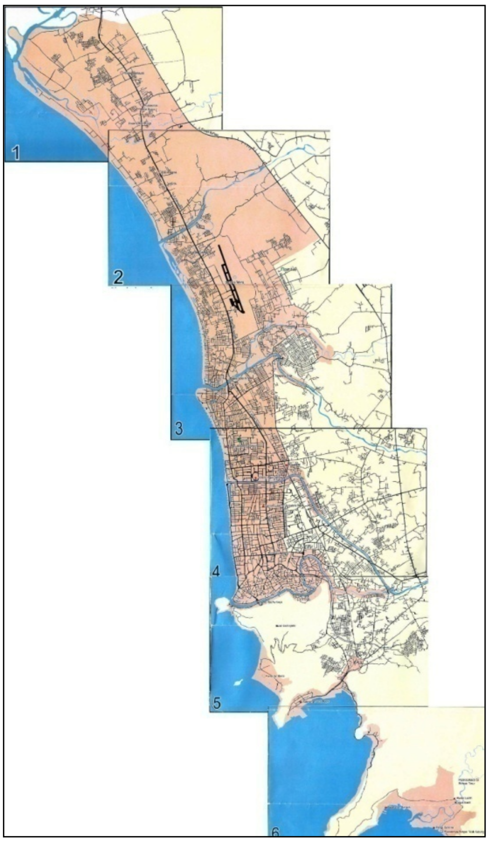
Situated in a low-lying coastal area, Padang (0°57′0″S 100°21′11″E), the capital city of West Sumatera province has a population nearly a million and serves as the nerve centre of West Sumatra economy. The city of Padang is the focus of tsunami vulnerability assessment in this study because most critical infrastructures in West Sumatera are located. The vulnerability of the city against the impact of tsunami has increased due to high concentration of residences in a ‘red zone’ or a zone with high risk of inundation according to the official tsunami hazard map (BPBD, 2010). The existence of critical infrastructures during any disaster events is very important to secure the processes of emergency responses, rehabilitation and reconstruction efforts.

Parfomak, (2008) defines critical infrastructures as “systems and assets, whether physical or virtual, so vital to a region (a city or a country) that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters”. Meanwhile, for the case of tsunami, we define critical infrastructures as infrastructures that directly or indirectly have significant role/contributions to the processes of live saving activities, emergency responses, and rehabilitation and reconstruction efforts. These infrastructures include shelters, banking and financial centres, commercial centre, religious facilities, energy sources, communication and IT networks, transportation system, government building/facilities, educational facilities, public health centre, food (livestock) and drinking water facilities, military facilities, manufacture/chemical industries, and emergency facilities (i.e. early warning system networks).

Many studies have been carried out to assess the vulnerability of buildings or infrastructures against the impact of tsunami as mentioned by Koshimura *et al.* (2009) and Omira *et al.* (2010). However, one of a methodologies with more complete parameters that has been used in many tsunami vulnerability assessment for buildings is Papathoma Tsunami Vulnerability Assessment method version 3 (PTVA-3). This method was originally developed by Papathoma and Dominey-Howes (2003) and has been used to assess building vulnerability in Greece, Italy, Maldives, and Perth, Australia (Papathoma *et al.*, 2003; Dominey-Howes and Papathoma, 2007; Dominey-Howes *et al.*, 2010; Dall'Osso *et al.*, 2010). Therefore, current study has an objective to assess the vulnerability of critical infrastructures in the city of Padang based on PTVA-3 approach. The details of this method will be explained in the following sections.

2. METHODOLOGY

General methodology of current study is started by determining possible earthquake and tsunami inundation in the city of Padang. This information can be obtained from the official tsunami hazard map released by BPBD Padang. The map is the results of research collaboration between many research institutions in Indonesia and Germany through the last mile project (Taubenböck *et al.*, 2009) (see Fig. 1). The second step is identification of critical infrastructures in the city of Padang. This step was carried out through field survey in August 2012. Later on, PTVA-3 calculates the Relative Vulnerability Index (RVI) for each analysed building by taking account physical aspects related to building structure and tsunami inundation. RVI is formulated as follows:



$$\mathbf{RVI = (2/3)SV + (1/3)WV} \qquad (1)$$

where:
SV : vulnerability of building structures with scores 1-5

WV : vulnerability of structure due to water intrusion with scores of 1-5

Fig. 1: Tsunami inundation map in Padang *(BPBD Padang, 2010)*

SV is calculated based on 13 building parameters such as; building materials, number of floors, hydrodynamics of the first floor, foundation types, maintenance conditions, number of basements, artificial coastal protections, building fences, building use, building orientation to the expected incident tsunami, number of building between the sea and the analysed building, and moving objects. All these parameters are measured and calculated using certain weighing factors. Meanwhile, WV is calculated based on the ratio of inundated floor(s) the total building floors. More detailed information can be found in Dominey-Howes *et al*. (2010) and Dall'Osso *et al*. (2010). The RVI is then determined based on the following levels:

Table 1: Determination of the relative vulnerability index (RVI)

Relative vulnerability index (RVI)	RVI score
Low	1.1>RVI ≥ 1.8
Moderate	1.8>RVI ≥ 2.6
Averaged	2.6>RVI ≥ 3.4
High	3.4>RVI ≥ 4.2
Very high	4.2>RVI ≥ 5.0

3. RESULTS AND ANALYSIS

A field survey carried out in August 2012 successfully identified 342 (three hundred and forty two) critical infrastructures in the city of Padang categorised in 15 groups namely: shelters (19 buildings), government facilities (40 buildings), education facilities (51 buildings), commercial facilities (82), religious facilities (40 buildings), banking and financial centres (19 buildings), public health facilities (10 hospitals), information technology and communication networks (9 buildings), agricultural and food facilities, drinking water facilities (1 storage), chemical and raw material industries (6 factories/storages), transportation facilities (38 buildings/bridges/facilities), military facilities (9 buildings), electricity generator/transmission system (3 plants/transmission systems), and fuel/energy facilities (14 networks/terminals). Those critical infrastructures are located in tsunami inundation zone based on BPBD tsunami hazard map (see Fig. 1).

Table 2: RVI for each group of critical infrastructures in Padang

Infrastructures	1*	2*	3*	4*	5*	Total
Education	19	13	6	11	2	51
Government	8	11	7	7	7	40
Commercial	19	26	5	24	8	82
Religious	9	13	6	6	6	40
Bank/financial	9	8	0	2	0	19
Health/ emergency	5	4	0	0	1	10
Drinking water	1	0	0	0	0	1
IT/ communication	4	3	0	1	1	9
Agriculture/food	1	0	0	0	0	1
Military	1	2	1	4	1	9
Chemical/ raw materials	1	0	0	0	5	6
Transportation	11	8	3	5	11	38
Power plant	1	0	1	0	1	3
Petrol/oil	7	1	0	2	4	14
Shelter	6	9	2	2	0	19
Total	102	98	31	64	47	342
Percentage	30%	29%	9%	19%	14%	100%

*) Notes for RVI:
1=low
2=moderate
3=averaged
4=high
5=very high

Considering 13 structural and tsunami parameters as required by equation (1), the calculation of RVI for each group of critical infrastructures are shown in Table 2. Table 2 shows that 14% of all critical infrastructures considered in current study are in very high vulnerability against tsunami, 19% high, 9% averaged, 29% moderate and 30% low. From each group of infrastructures, chemical and raw material industries have the highest percentage of critical infrastructures with very high RVI (83%). This conditions occur because most of these facilities are located in Teluk Bayur Port which is located right in the coastline with tsunami inundation height is predicted between 5 - 6 m.

Besides providing RVI for each infrastructure, current study also will produce maps showing the locations of critical infrastructures and their RVI as shown exemplarily in Fig. 2. These preliminary results will be further investigated and validated by the second field investigation in November 2012 and Forum Group Discussion with the stake holders in October and November 2012. We hope that the obtained results from current study will help the local government and other related institutions who are dealing with disaster mitigation will get benefits particularly for the management of emergency response, rehabilitation and reconstruction efforts.

4. CONCLUSION AND REMARKS

A preliminary result of tsunami vulnerability for critical infrastructures in the city of Padang has successfully assessed 342 infrastructures in which 33% of them have high and very high Relative Vulnerability Index (RVI). The results hopefully will contribute to the disaster management or any disaster risk reduction programmes for the city of Padang. For example, the city of Padang has developed a master plan for the relocation of governmental facilities and other critical infrastructures to the “new city centre”. Therefore, the results from this study will be useful for the execution of this plan in order to minimize the impact of tsunami in the future.

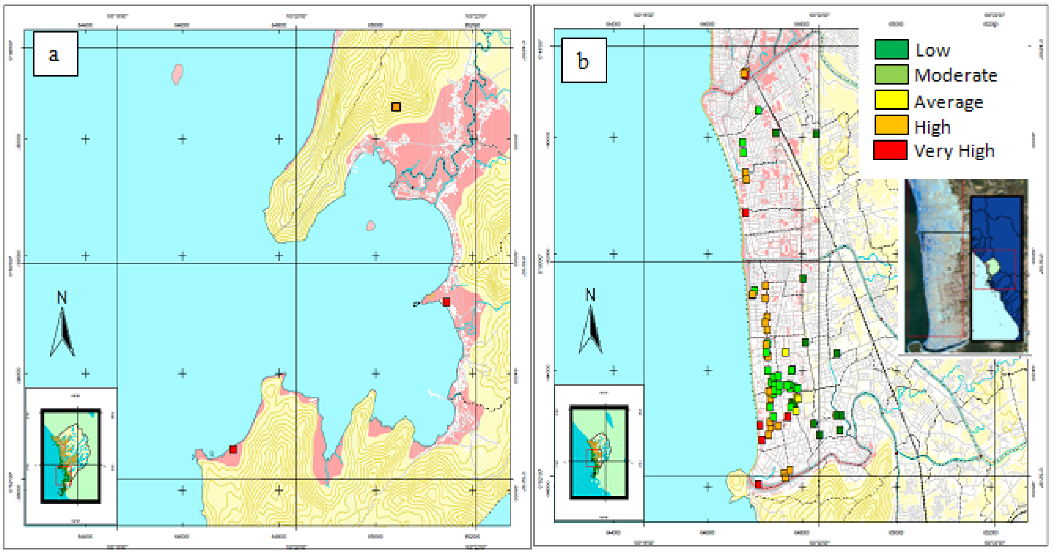


Fig. 2: Examples of maps for critical infrastructures with RVI indicators

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