

Rapid Visual Screening Method for Seismic Vulnerability Assessment of Existing Buildings in Bukit Tinggi, Pahang, Malaysia

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Abstract—Bukit Tinggi may experience low earthquake hazard but are still at high risk of substantial damage and loss. Dense concentration of buildings and infrastructure in some areas mainly due to the hospitality industry can generate this high risk level. This study is focused on identify, inventory and rank buildings in Bukit Tinggi to assess seismic vulnerability buildings. The methodology is based on the rapid visual screening (RVS) procedure. Major parameters that have effects on the building score are primary structural lateral-load-resisting system, construction material, and other seismic related characteristic such as soil type and building irregularity. Building with higher S scores corresponding to better seismic performance. Most of the buildings in Bukit Tinggi are less seismic risk 74% while another 26% considered in need of further evaluation.

Keywords—Rapid Visual Screening, FEMA 154, Bukit Tinggi

I. Introduction

Earthquake is one of nature's greatest catastrophic threat to human kind and other living creatures as well as properties. An earthquake is the result of sudden release energy in the earth's crust that generates seismic wave. Malaysia is situated at the Sunda Plate, which is considered to be stable tectonically. However, it is surrounded by the country of Pacific Ring such as Sumatran Indonesia and Philippines. The impact from surrounding countries can affect Malaysia.

Rapid Visual Screening (RVS) is a qualitative seismic vulnerability assessment method (Yadollahi, Adnan, & Zin, 2012). The RVS method was designed to be the preliminary assessment for identifying potentially hazardous structures. RVS enable users to classify the surveyed buildings into two categories; those acceptable as to risk to life safety or those that may be seismically hazardous and should be evaluated in more detail by a design professional.

Detailed seismic vulnerability evaluation is a technically complex procedure and can only be performed on a limited number of buildings. It is, therefore, very important to use simpler procedures that can help to rapidly evaluate the vulnerability profile of different types of buildings, so that the more complex evaluation procedures can be limited to the most critical buildings (Sinha & Goyal, 2004).

This research is to focused on identify, inventory and rank buildings in Bukit Tinggi to assess seismic vulnerability buildings through RVS method. A numerous of guidelines are available from Federal Emergency Management Agency (FEMA) in United States for seismic risk assessment and rehabilitation of buildings. RVS method has been widely implemented in US and other countries as a tool for ranking the buildings regarding seismic vulnerability considerations. For instance, Arintonang, Satyarno, & Supriyadi (2011) applied the RVS method as a preliminary evaluation to determine the level of performance suitability of the Emergency Care Installation Buildings of Dr. Sardajito Hospitals for the effects of earthquake. Wallace & Miller (2008) screened 1,057 public buildings in western Oregon counties in US. They implemented RVS to identify potential seismic hazards for Oregon's public facilities, including hospitals, schools, police stations, fire stations, community colleges, and emergency response centers. In addition, Kapetana & Dritsos (2007) used RVS to identify, inventory and rank all high-risk buildings in a specified region in Greek to form a strategy of priority based interventions to buildings.

II. Study Area

According to Mineral and Geoscience Department Malaysia JMG by Yan et al. (2011) Peninsular Malaysia is tectonically surrounded by the relatively stable Sunda plate. Though, it is bordered by two active seismically zones; Sumateran Subduction Zone and Philippines Subduction Zone.

Bukit Tinggi is a small town in the Bentong district in Pahang that located 50 km from Kuala Lumpur and 34 km from Bentong which accessible by Kuala Lumpur – Karak Expressway. This town is famous with the cool weather and its serenity. The place is ideal for those who wanted to forget a moment the bustles of cities especially those who lived in Kuala Lumpur as its distance is about 1 hour drive away. Figure 1 illustrates the location of Bukit Tinggi in map of Malaysia.



Figure 1. Location of Bukit Tinggi, Bentong, Pahang

However, this town was disrupted by the earthquake event that has been recorded by Malaysian Meteorological Department (MMD) on 30th November 2007, not once but thrice just for that day with magnitude ranging M 2.9 to M 3.6 (Yan et al., 2011). Since that a numbers of weak earthquakes have occurred around Bukit Tinggi area. Therefore, Peninsular Malaysia is no longer an earthquake-free zone. The epicenters appear to be distributed along Bukit Tinggi (northwest-southeast) and Karak (northerly direction) fault zone. Figure 2 displays the location of most of the epicentres that located within a 6.5 km radius around Bukit Tinggi, Pahang.

On 8th October 2009, MMD has reported eight more minor earthquakes occurred in the Bukit Tinggi area between 4.45 am and 12.05 pm but the magnitude and exact location was unknown. Once again, on 4th December 2009 a weak earthquake was recorded (Yan et al., 2011).

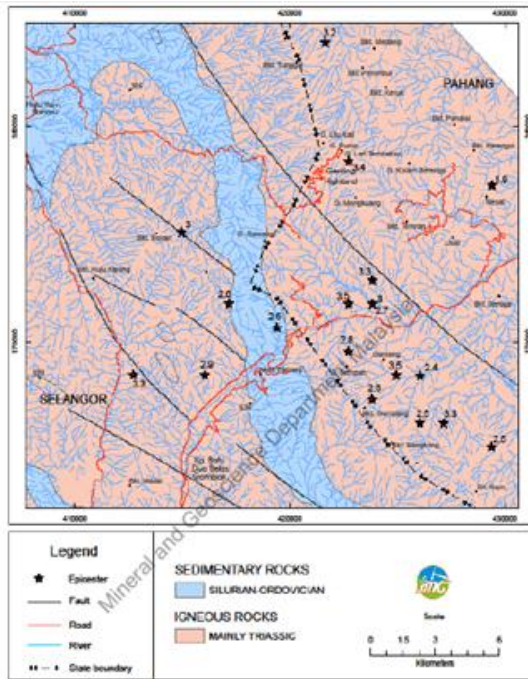


Figure 2. Epicenters of the Bukit Tinggi earthquake in the epicentral area (Lat C.N. and Ibrahim A.T., 2009)

III. Methodology

A. RVS Method

The RVS method is designed to be implemented without performing any structural calculations. It is fast and relatively inexpensive without detailed analysis of potential hazardous building. Buildings are rapidly evaluated via a “sidewalk survey” to identify features that affect the seismic performance of the building (FEMA, 2002).

The RVS method is conducted by filling the form of FEMA 154 as illustrated in Figure 3. Various features were considered during this evaluation stage. These features may include building type, seismicity, soil conditions and irregularities. The inspection, data collection and decision-making process typically occurs at the building site, and is expected to take around 20 min for each building.

BUILDING TYPE	W1	W2	S1	S2	S3	S4	S5	C1	C2	C3	PC1	PC2	RM1	RM2	URM
Basic Score	5.2	4.8	3.6	3.6	3.6	3.6	3.6	3.6	3.0	3.6	3.2	3.2	3.6	3.4	3.4
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.4	+0.2	+0.4	0.2	0.2	+0.4	+0.4	+0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-3.0	-2.0	0.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
FINAL SCORE S	0.8														

Figure 3. Fullfilled FEMA 154 Moderate Seismicity data collection form

The results of this evaluation are then compared with the cut-off score, which is equal to 2. It estimated the possibility that the building will collapse if ground motions occur. If a building is scored more than 2, then the building is considered to have sufficient ability to resist earthquake load. Conversely if the score is less than 2, then the building should be further evaluated because it is considered vulnerable to earthquakes.

B. Building Classifications

Based on the design material in the study area, Bukit Tinggi, most of the buildings were made of wood, steel, and concrete. Table 1 shows the shows that the types of buildings involve in Bukit Tinggi based on design material.

Table 1. Types of building involve in study regions

Building Type	Description
W1	wood buildings mostly made by seasoned wood having floor and roof framing consisting of wood joists or rafters on wood studs
S1	types of buildings consist of a steel frame with floor and roof framing consisting of cast-in-place concrete slabs or metal deck with concrete fill supported on steel beams, open web joists or steel trusses
C1	types of buildings consist of a moment resistant frame assembly of cast-in-place concrete beams and columns
C2	building types are same as C1 types but have shear walls to resist the lateral loads of the building
C3	type of buildings are an older type of building construction that consists of a frame assembly of cast-in-place concrete beams and columns where infill walls are constructed of solid clay brick, concrete block or hollow clay tile masonry.

IV. Result and Discussion

Six general building occupancies that are easy to recognize have been defined. They are listed on the data collection form as Residential, Commercial, Industrial, Educational, Government, Assembly, History and Emergency Services. A total of 1166 were identified in Bukit Tinggi. In the Figure 4 highest occupancy class percentage is residential, 84 percent. According to FEMA 154 (FEMA, 2002), this occupancy refers to all residential building such as houses, dormitories, motels, hotels, apartments and condominium. Besides of the villagers houses, many knows that Bukit Tinggi is one of the tourist spot in Malaysia, indeed many hotels industry has been developed here that contribute to the highest percentage of residential building occupancy in the area.

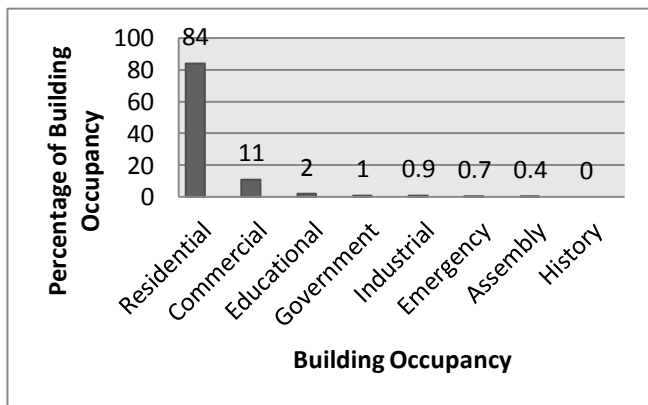


Figure 4. Percentage of building occupancy in Bukit Tinggi

Table 2 indicates the results of preliminary visual inspection were completed for these buildings. Figure 5 is the

vulnerability map of Bukit Tinggi developed from the result of RVS procedure. From the total of 1166 buildings in Bukit Tinggi, 26 percent of the buildings indicated as 'Yes' meaning that the buildings need to be further evaluate by the professionals based on engineering practice because the buildings has probability to damage due ground motion activity. Whereas, another 74 percent of buildings are safe from the ground motion. The results revealed that the score determined for the factor of primary structural lateral load-resisting system (building types), has the highest contribution to the final score of the buildings. Different system has different basic score. As an example, a concrete structure has lower basic score (± 4.0) than wood structure (± 6.0).

Table 2. Result from rapid visual screening

Building Occupancy	Number of Buildings	Percentage Buildings per Area (%)	Number of Detailed Evaluation Buildings	
			YES	NO
Residential	979	84.0	195	784
Commercial	128	11.0	100	28
Industrial	10	0.9	0	10
Educational	23	2.0	5	18
Government	13	1.0	4	9
Assembly	5	0.4	2	3
History	0	0	0	0
Emergency	8	0.7	2	6
TOTAL	1166	100	308	858

Other than that, most of the multi-story buildings has soft story which is a large opening at the ground level commonly for parking area. The buildings in Bukit Tinggi are on a steep hill so that over the up-slope dimension of the building the hill raises at least one story height. A problem may exist because along the lower side of the story, the horizontal stiffness may be different from the uphill side. Additionally, the stiff short columns attract the seismic shear forces and may fail. These contribute the reduction of the final score due to the vertical irregularity.

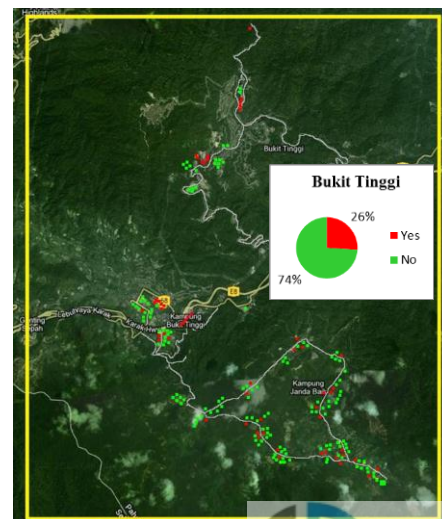


Figure 5. Vulnerability map of Bukit Tinggi

v. Conclusion

From the study in this research, the conclusions that can be drawn are as follows:

(i) Rapid Visual Screening method using FEMA 154 is a simple method in preliminary screening phase to identifying potentially hazardous buildings, the fastest tool to analyse building, cheaper and easy to use.

(ii) Most of the buildings in Bukit Tinggi are still considered as less seismic risk (74%), while another 26% considered in need of further evaluation.

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