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Vulnerability Assessment of Buildings in Ranau Township: Methodological Design

(Penilaian Kerentanan Bangunan di Perbandaran Ranau: Reka Bentuk Metodologi)

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ABSTRACT

Structural damage usually happens during earthquake events. This had caused damage of properties and even worse, loss of lives. Usually, the greatest losses were not caused by the quake specifically, but rather because of the fall of the structures. The vulnerability is a degree which buildings are exposed to harmful and destruction and in this case, it's to earthquake incident. The fast development in urbanization prompt higher hazard from earthquake occurrences; including in the area with intermediate earthquake activities city like this city. This study addresses the expeditious assessment of a great number of buildings in Ranau Township involving measures to identify hazards, evaluate building stocks and calculate vulnerability using a scoring method, FEMA 154 form. The selected area was selected based on building data from the local municipality. Two types of buildings were assessed; commercial buildings and residential buildings. The basic structural score was determined based on building types. Modifier score is a major factor that gives impacts to structural performance during earthquake. These two types of scores will determine the final score of the building and its vulnerability. The outcome of the study reveals a different vulnerability level where early precaution and modification are needed because of the high vulnerability risk. This method can be applied for further analysis in other seismic-prone areas.

Keywords: Vulnerability; Visual screening; Ranau; Seismic risk

ABSTRAK

Kerosakan struktur biasanya berlaku semasa kejadian gempa bumi. Ini telah menyebabkan kerosakan harta benda dan lebih buruk lagi, kehilangan nyawa. Kebiasannya, kerugian terbesar tidak disebabkan oleh gempa secara khusus, tetapi kerana keruntuhan struktur. Kerentanan adalah tahap bangunan terdedah kepada bahaya dan kemusnahan dan dalam kes ini, ia adalah kejadian gempa bumi. Perkembangan pesat dalam sektor pembandaran mengakibatkan bahaya yang lebih tinggi akibat kejadian seismik; walaupun di kawasan yang mempunyai aktiviti seismik sederhana seperti bandar ini. Kajian ini membincangkan penilaian pesat sejumlah besar bangunan di perbandaran Ranau yang melibatkan langkah-langkah untuk menentukan bahaya, menilai kerangka bangunan dan pengkomputeran dengan kaedah pemarkahan menggunakan borang FEMA 154. Kawasan Ranau dipilih berdasarkan data bangunan dari perbandaran tempatan. Dua jenis bangunan telah dinilai iaitu bangunan komersial dan bangunan kediaman. Skor struktur asas ditentukan berdasarkan jenis bangunan. Skor pengubah adalah faktor utama yang memberikan impak kepada prestasi struktur semasa gempa bumi. Kedua-dua jenis skor ini akan menentukan skor akhir bangunan dan tahap risiko ia terdedah kepada bahaya (kerentanan). Hasil siasatan mendapati tahap kerentanan yang berlainan dan kawasan-kawasan di mana langkah awal pencegahan dan pengubahsuaian diperlukan kerana risiko terdedah kepada bahaya adalah tinggi. Kaedah ini boleh digunakan untuk analisis lanjut di kawasan lain yang mengalami aktiviti seismik.

Kata kunci: Kerentanan; Pemeriksaan visual; Ranau; Risiko seismik

INTRODUCTION

The fast development in urbanization prompt higher seismic hazard, even in moderate seismicity like Ranau. Recent seismic activities around the world have shown that sustainable solutions need to be identified to reduce the catastrophic effects of earthquakes. (Hossain et al. 2013). Earthquake usually happens when the rocks underground suddenly break along the faults because of a sudden release of energy which forms seismic waves that will result in ground shaking. It is a destructive natural phenomenon that causes great damage either to the buildings or to the inhabitants in the area. In Sabah, there are three primary earthquake zones, namely the Central- North(Ranau) Zone, the Dent-Semporna Peninsula Zone, and the Labuk Bay-Sandakan Basin Zone (Figure 1) (Tongkul 2015).

There are three main destructive earthquakes had happened in these zones which in 1976, 1991, 2015 and most recently were on March 2018 and had caused substantial damages. In addition to the local earthquakes, East Malaysia is also affected by tremors originating from large earthquakes located over Southern Philippines and Northern Sulawesi ((MET) 2016). Sabah still receives compression forces as three main tectonic plates interact. Sabah is actually on the southeast Eurasian Plate bordering the Philippine Plate and the Pacific Plate. The Philippine Plate and the Pacific Plate collided with the Eurasian Plate in the West at a rate of approximately 10 cm per year. In addition, the southern part of the Australian plate moves north at a speed of 7 cm per year, which is the most active and unstable. Although Sabah is 1,000 km from the plates, it can still experience the compression force (Hossain et al. 2013). Since this destructive natural phenomenon cannot be predicted and prevented, it’s crucial to investigate building durability and susceptibility in the critical zones to prevent higher destruction and damage to the properties and inhabitants life.

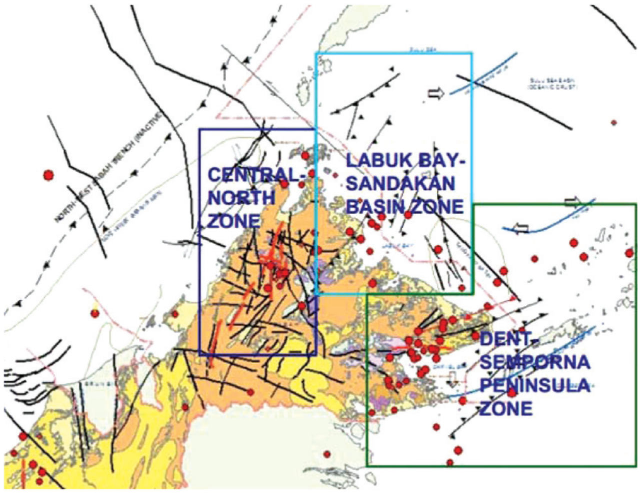


FIGURE 1. Seismic zone of Sabah (Tongkul 2015)

VULNERABILITY ASSESSMENT

A vulnerability is a degree which buildings are exposed to a harmful and destruction risk. Reported damages from earthquake indicate susceptibility of existing structures and significance of seismic retrofit execution. One of the principle fixings in a loss model is an exact, straightforward and thoughtfully stable calculation to evaluate the seismic vulnerability of the building stock and surely numerous instruments and procedures have been proposed in the course of recent years for this reason (Calvi & Pinho 2006). This is attributable to a progression of dangerous factors, for example, the age of the structures, the low quality of the auxiliary frameworks and the inadequate support of structures (Chaibedra et al. 2018).

To assess seismic risk, it requires assessment of an extensive building population in a brief timeframe by a basic but robust strategy, capable of quantifying the seismic performance of buildings and using vulnerability as an input parameter. Detailed analyses of vulnerability assessment are time-consuming and these evaluations correspond to the methods of structural analysis and design. The main disadvantage is that they should be performed for every investigated building individually, so alternative methods like RVS have been developed to enable the rapid evaluation of large building stock (F. Shah et al. 2016). Visual screening methods, based on systems calibrated by experts, allow for the quantification of structural vulnerabilities more easily than analytical approaches (Calvi 1999). Detailed calculations and multiple scenarios are not needed in this method. Another method is the score assignment which will determine seismically hazardous structures by structural deficiencies identification. To determine the level of destruction indicates by the severity of a potential seismic event, quantitative information is gathered using parameters which includes; material quality, type of foundations, state of conservation, number of stories, and structural rigidity. From the correlations between damage and structural properties observed, the potential structural deficiencies were identified. The main aim of this method is to ascertain whether or not a particular building requires a more detailed investigation. Score assignment methods have been successfully applied recently to seven European cities in the RISK-UE European project (Mouroux et al. 2004).

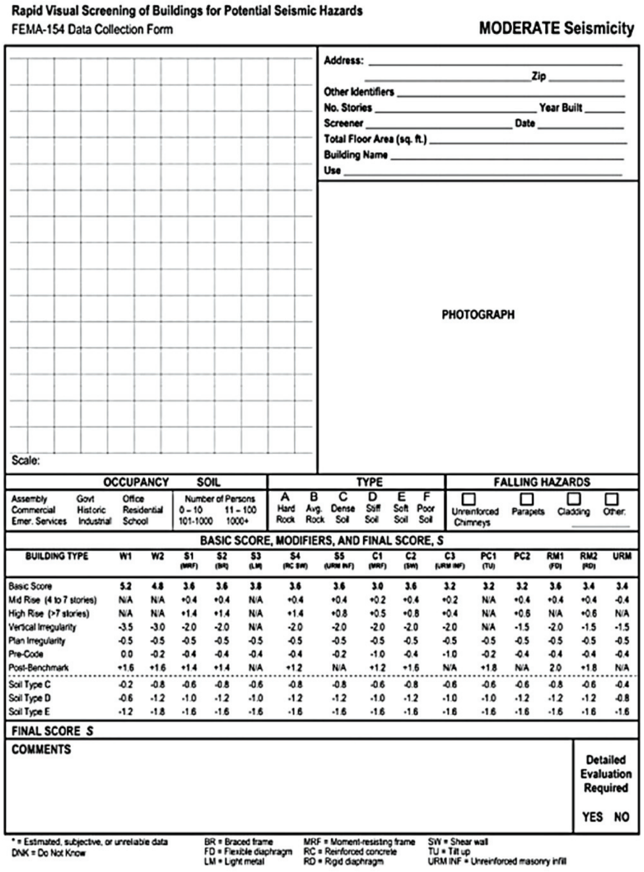
RVS or rapid visual screening is one of the most suggested techniques for seismic vulnerability assessment and can be executed without any structural computations, but using a visual survey on the sidewalk of a building and filling in the surveyor's data collection form. (Federal Emergency Management Agency (FEMA) 2015). Visual evaluation methods, based on systems calibrated by experts, allow for the quantification of structural vulnerabilities more easily than analytical approaches which do not need the detailed calculations and multiple scenarios (F. Shah et al. 2018).

RAPID VISUAL SCREENING METHOD (RVS METHOD)

Rapid visual screening (RVS) is a technique to evaluate the vulnerabilities of the buildings when an earthquake occurs. It is a visual evaluation using RVS form proposed. By collecting information about the condition of the building stock and the predicted damages, this method can facilitate prevention so authorities can strengthen the most vulnerable buildings in order to mitigate risk. Besides that, RVS also requires less expertise and time for each building (F. Shah et al. 2018).

In this study, FEMA 154 data collection form has been used. There are eight sequences in implementing RVS of buildings which are; 1) develop budget and cost estimate, 2) pre-field planning, 3) choosing and revise the data collection form, 4) selecting and training of screening personnel, 5) procurement and analyze of pre-field data, 6) review of current building plan, 7) field screening of buildings, and 8) verify the quality and documenting the screening information in the database. FEMA 154 has three types of data collection form which is low, moderate and high seismicity. The selection of the form is based on the seismicity region. In this study, the moderate form had been used (Figure 2).

Based on Figure 3, there are few criteria were surveyed on each building to obtains the final score. The criteria including; occupancy, soil types, falling hazards, building types, vertical irregularity, plan irregularity, pre-code and post benchmark. The description for each criterion will be elaborated below;



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form
MODERATE Seismicity

Address: ______
______ Zip ______
Other Identifiers ______
No. Stories ______ Year Built ______
Screener ______ Date ______
Total Floor Area (sq. ft.) ______
Building Name ______
Use ______

PHOTOGRAPH

Scale:

OCCUPANCY			SOIL	TYPE	FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock B Avg. Rock C Dense Soil D Stiff Soil E Soft Soil F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ______

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

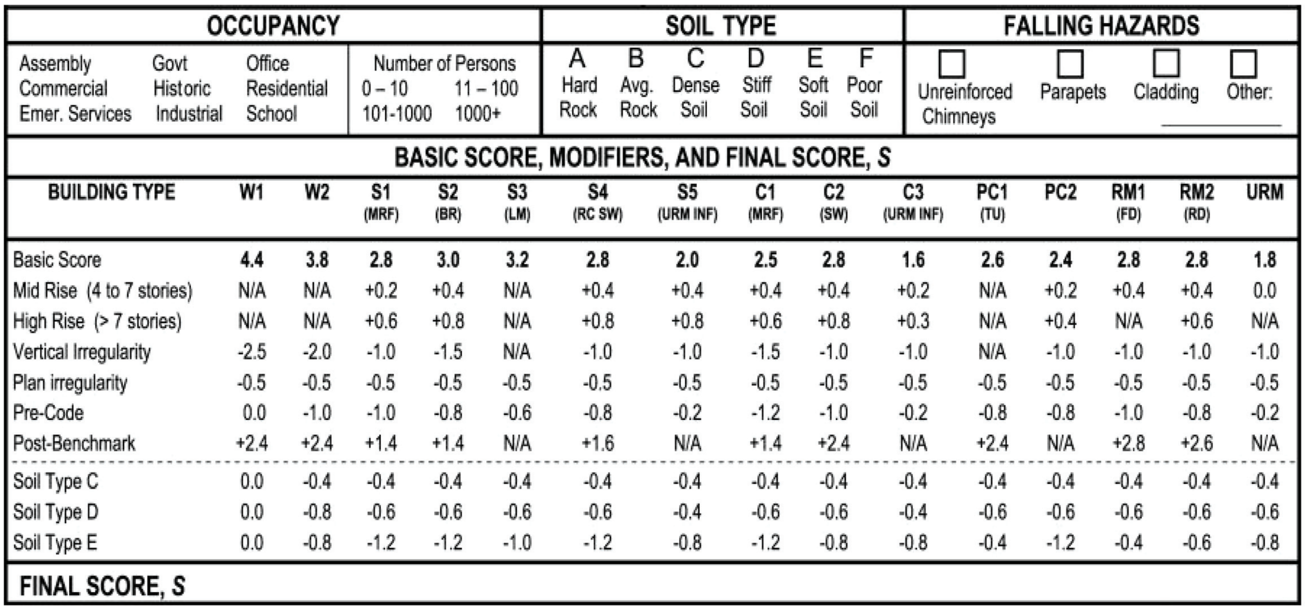
BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	5.2	4.8	3.6	3.6	3.8	3.6	3.6	3.0	3.6	3.2	3.2	3.2	3.6	3.4	3.4
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
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	-2.0	-2.0	-2.0	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	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
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*															

COMMENTS

Detailed Evaluation Required
YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

FIGURE 2. The sample of FEMA 154 data collection form



OCCUPANCY				SOIL TYPE	FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock B Avg. Rock C Dense Soil D Stiff Soil E Soft Soil F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ______

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
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	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, *S*															

FIGURE 3. The criteria in FEMA 154 form used during surveying

Occupancy: This is to calculate the maximum occupancy load for each building according to its usage and total floor area (Table 1)

Soil types: The information about the soil types can be obtained from the government agency. Only soil with types C, D, and E will be a given score. Type C soil is soft rock or solid soil, Type D soil is stiff soil and Type E soil is soft soil.

TABLE 1. Occupancy load based on building usage

Building usage	Square feet, per person
Assembly	Varies, 10 minimum
Commercial	50-200
Emergency Services	100
Government	100-200
Industrial	200-500
Office	100-200
Residential	100-300
School	50-100

The falling hazards are any exterior falling hazards that can be seen on the buildings such as an unbraced chimney, parapets, heavy cladding, and appendages. This considers hazardous since it could separate from the building during an earthquake and bring damages.

Structural types of buildings can be classified into 15 types and explained below in Table 2.

TABLE 2. Classification of types of buildings

Structural types	Description
W1	Light wood frame, residential or commercial, <5000 square feet
W2	Wood frame buildings, > 5000 square feet
S1	Steel moment-resisting frame
S2	Steel braced frame
S3	Light metal frame
S4	Steel frame with cast-in-place concrete shear walls
S5	Steel frame with unreinforced masonry infill
C1	Concrete moment-resisting frame
C2	Concrete shear wall
C3	Concrete frame with unreinforced masonry infill
PC1	Tilt-up construction
PC2	Precast concrete frame
RM1	Reinforced masonry with a flexible floor and roof diaphragms
RM2	Reinforced masonry with rigid diaphragms
URM	Unreinforced masonry bearing-wall buildings

Vertical irregularity: The building considered to have vertical irregularity when there are ventures in ascent view; slanted dividers, constructed on highland; it is a delicate story; and structure with short columns.

Plan irregularity: The building is considered to have plan irregularity if it is torsional irregularity (the lateral system does not appear to be relatively well distributed in either or both directions, non- parallel system(there are one or more major vertical elements of the lateral system which are neither orthogonal to one another, reentrant corner (both interior corner projections exceed 25 percent of the overall plan dimension in that direction), diaphragm opening with a width of more than 50 percent of the total diaphragm width at that level, eccentric planning rigidity (corner building, wedge-shaped building with one or two solid walls and all other open walls). The soft story is included as the vertical irregularities category namely the vertical stiffness irregularity. The most frequent cause of structural failure in the irregular vertical part of a building when a major earthquake occurs is the stiffness of irregular configuration/soft story which left behind many victims (Teddy et al. 2018)

Pre-code: a building designed and built before the year in which seismic codes were first adopted and enforced in the jurisdiction; the default is 1941, with the exception of PC 1, 1973.

Post benchmark: a building designed and built after significant improvements in the requirements for seismic code has been adopted and enforced; the benchmark year in which codes are improved may differ for each type of building and for each jurisdiction.

The formula to calculate the RVS final score as shown below (1).

$$\text{Final Score (S)} = \text{Basic Score (BS)} + \text{Score Modifiers (SM)} \qquad (1)$$

The calculated final score will be grouped according to five damage grade as shown in Table 3. Grade 1 shows that the building is insignificant because of minor damage and no structural damage. Grade 2 means moderate damage where slight structural damage occurs with cracks in the frame columns and beams and in the walls. Grade 3 is significant to severe damage with cracks in columns and beam-column joints when frames are located at the base and joints of coupling walls. Grade 4 is very serious damage in which some columns or a single upper floor collapse. Grade 5 means that it is destructive when parts of the building collapse on the ground floor.

TABLE 3. Structural score with damage potential (Monteiro et al. 2016)

Rapid Visual Screening Score	Damage Potential
S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 2.5	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 2.5	A probability of Grade 1 damage

RVS IN RANAU TOWNSHIP

To understand precisely the criticality of earthquakes in Ranau, its geographical profile and climatic factors were taken into account. Ranau is situated at Latitude 5° 30' U and 6° 25' U and Longitude 116° 30' and 117° 5' T. The region's climate is characterized by a cool breeze and a moist feel.

The most active fault zone in the country is Central-North (Ranau), with a total of nine fault lines affecting Tuaran, Penampang, Tambunan and Ranau in particular (Harith & Adnan 2017). Ranau is in the Central-North zone and Crocker fault zone (CFZ) is situated in this Central-North zone as shown in Figure 4 (Tjia 2007). CFZ is an active fault zona which extends from Tenom in the south. The active and potentially active faults segments of CFZ are; Mamut, Mensaban, Lobou-Lobou, Nalapak, and Parancangan faults (Tongkul 2015). Table 4 shows a series of the earthquake in Ranau from 1995 until March 2018 (United States Geological Survey (USGS) 2018; Tongkul 2015; (MET) 2016). This gives an idea of the need for a detailed study based on the priority of vulnerability and proposes measures for the same area. (Sarmah and Das 2018)

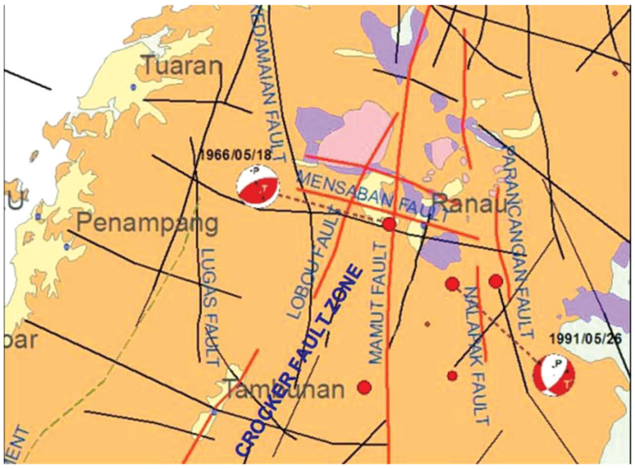


FIGURE 4. Crocker Fault Zone (Tjia 2007)

TABLE 4. A series of the earthquake in Ranau (Tongkul 2015; (MET) 2016; United States Geological Survey (USGS) 2018)

Date	Magnitude
1995-08-11	4.1M
2006-09-28	4.5M
2014-02-01	4.7M
2015-06-05	6.0 M
2016-03-17	2.7M
2016-04-16	3.0M
2016-05-14	3.6M
2016-08-26	4.0M
2018-03-08	5.3M

CASE STUDY: EXAMPLE OF RVS

Figure 5 shows a sample of form filled-up during surveying during Rapid Visual Screening. This sample is used to describe in details the procedure during RVS. The surveyed building is a residential house located at Kampung Lingkudau. Photos of the building need to be captured to make identification easier if further detailed evaluation required. The sketch space was used to sketch the floor map to calculate the total floor area. For residential, the occupancy loads per person is 100-300 sq.ft. Thus, this house can accommodate a maximum of 15 people at times because its total area is 1550 sq. ft. The soil type of the house is B; average rock. Basic score depends on the structural types of buildings. This building is grouped as W1; light wood frame with less than 5000 sq. ft.; thus the score for W1 is 5.2. For score modifier features, it has vertical irregularity because it is a soft story (house over garage). The score for vertical irregularity is -3.5. This building doesn't have any plan irregularities. Thus, the final score for this building is calculated as below;

$$\begin{aligned} \text{Final Score (S)} &= \text{Basic Score (BS)} \\ &\quad + \text{Score Modifiers (SM)} \\ &= 5.2+(-3.5) \\ &= 1.7 \end{aligned}$$

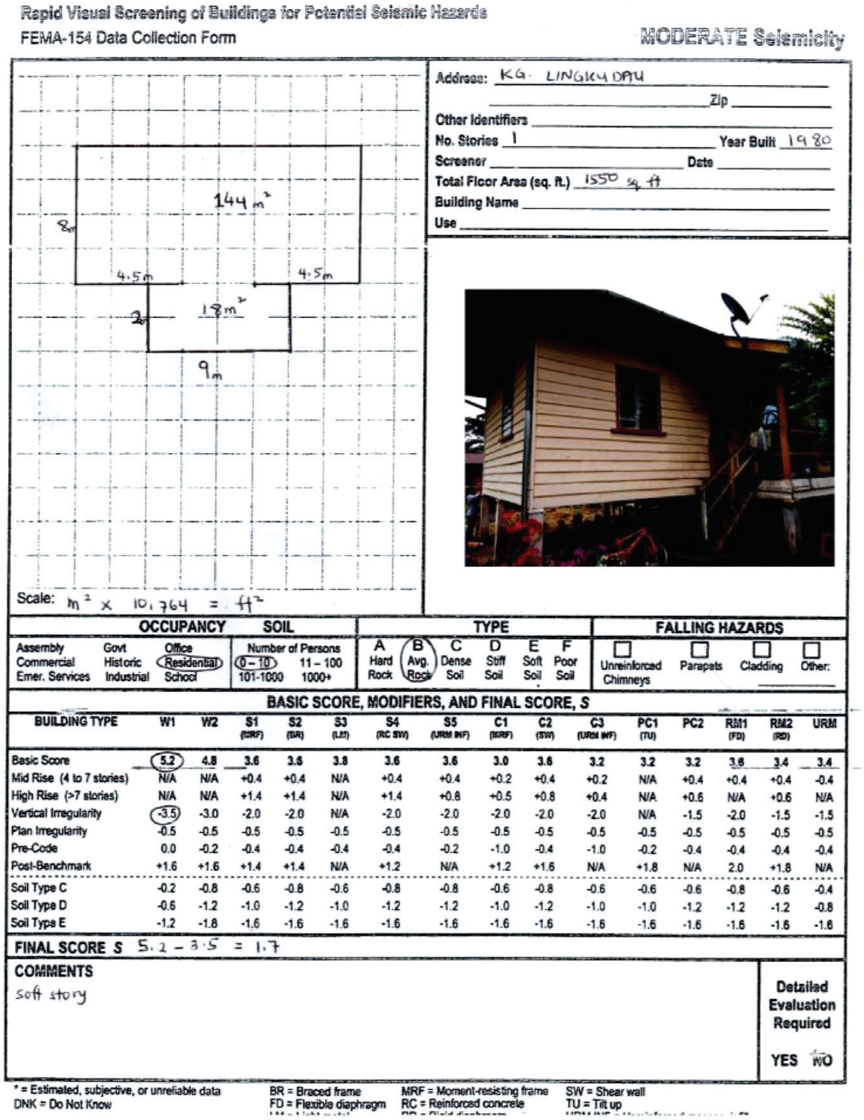
As shown in Table 3, 1.7 is marked as a high probability of Grade 3 damage; very high probability of Grade 2 damage.

RESULTS AND DISCUSSIONS

The data were collected from both primary and secondary sources following sample size selection. Primary data were collected through RVS by visiting the earthquake-prone areas and supported by photographs, while secondary data collection from various departments and authorities was carried out. This helped us to know the city's risk vulnerability profile and how the city and its people handled earthquakes in the past. Due to inadequate design and/or construction of RC frame components, these buildings essentially behave like masonry shear wall structures with a shear-dominant failure mechanism (Lizundia et al. 2017). The vulnerability of the building is due to older design codes, poor design practices and poor enforcement of the code. Most of these buildings are currently in operation and need further evaluation and upgrading to minimize seismic damage and improve the safety of life (Barbat et al. 2010).

In this case study, there are 245 buildings have been screened and among this, 21 buildings are in grade 3 damage, 11 buildings are in grade 2 damage and other buildings are in grade 1 damage. Almost all of the buildings in grade 3 and grade 2 damage are residential house build with wood and positions near or on the hill. Since Ranau had the history of earthquake, the authorities had enforced strict guidelines in building construction. Thus, a majority the earlier built-up buildings are in grade 3 and 2 damage. In addition, the new requirements limit the newly constructed buildings must not more than 4 stories to minimize the damage if the earthquake occurs in the future.

Most of the multi-story RC buildings have not been engineered and sustained significant damage during the



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form
MODERATE Seismicity

Address: KG. LINGKU DAU
Zip
Other Identifiers
No. Stories 1 **Year Built** 1980
Screener **Date**
Total Floor Area (sq. ft.) 1550 sq. ft
Building Name
Use

Scale: m² x 10.764 = ft²

OCCUPANCY			**SOIL**	
Assembly	Govt	Office	Number of Persons	
Commercial	Historic	[✓ Residential]	[✓ 0 – 10]	11 – 100
Emer. Services	Industrial	School	101-1000	1000+

TYPE					
A Hard Rock	[✓ B Avg. Rock]	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil

FALLING HAZARDS
☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	**W1**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**
Basic Score	[✓ 5.2]	4.8	3.6	3.6	3.8	3.6	3.6	3.0	3.6	3.2	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	+0.2	+0.4	+0.2	N/A	+0.4	+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	-2.0	-2.0	-2.0	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	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
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 5.2 – 3.5 = 1.7

COMMENTS
soft story

Detailed Evaluation Required
YES [✓ NO]

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
MRF = Moment-resisting frame
RC = Reinforced concrete
SW = Shear wall
TU = Tilt up

FIGURE 5. The sample of filled up form during surveying

earthquake before. Those project failures therefore urgently need to carry out the seismic vulnerability assessment of buildings and propose possible retrofitting solutions. As the detailed evaluation of buildings is a complex and costly task, it cannot be carried out in all buildings in an area. Past acknowledgment reports suggest that a simple evaluation of existing buildings such as RVS is needed (Ajay et al. 2017).

The limitation that were faced during the RVS survey includes; i) misunderstanding types of construction or the building structures; ii) limited access to certain buildings; and iii) residents not participating (Mohamad et al. 2018). This causes few buildings not evaluated because of the owner of the buildings not permitted to carry the survey. The improvement of the safety level for new structures can be very costly and cost-effective even in areas with low to medium seismicity. The upgrade costs can be disproportionately high in relation to the advantages of reducing the seismic risk. Specific risk-based rules in seismic codes for existing structures are required to avoid inefficient resource allocation.

CONCLUSION

The results from this study are important to the authorities in Ranau town to ensure all the buildings are safe and have less potential for damage when an earthquake happened. It also is a guideline to all resident near Ranau town to take precaution if their buildings are grouped in grade 3 and 2 damage. The result would be more precise if all building owner gives cooperation in the surveying process. RVS is important as an early warning to the owner of building and authorities to do damage management in the future. This research will contribute to the use of this map by planners and developers to identify roads and settlements affected by future earthquakes. The results of this study should be used in the preliminary mapping of seismic hazards and in a detailed analysis of the quantitative risks. The map produced could be very useful for local and community officials in selecting the appropriate locations for future land use planning and development based on the prediction of seismic risk mapping.

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