Seismic Vulnerability Assessment of Selected High-Rise Building in Lae City, Papua New Guinea -

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Abstract

Traditional houses in PNG are built from natural materials, usually fairly light structures. The threat of earthquake impact on people's safety is less than in modern modernized building such as the permanent structures and the high-rise building. The current building codes being used are our-dated and being revised with the assistance of Australian professionals. The high-rise building in the second largest city and industrial hub of Papua New Guinea, Lae City, is believed to be vulnerable to earthquake impact, thus this study. The assessment methods use is the Rapid Visual Screening (RVS) technique, which uses visual inspection of the exterior and interiors of the building and recording it in a survey form. It is the most prominent seismic vulnerability evaluation method that is widely employed. The selection of building to for inclusion in the is based on the criteria of more than three floor building and found four available in Lae City. The collected data contains the building identification, building information, comments, photographs and sketches, basic score, modifiers and final score parts. Added are the extent of review, other hazards and actions required. The results show that the buildings in the study can withstand an earthquake. It was confirmed when the earthquake of September 11, 2022 occurred, which measured at 7.6 magnitude.

Keywords: earthquake, risk, vulnerability, survey inspection forms, infrastructure, rapid visual screening technique

1 Introduction

Papua New Guinea (PNG) is one of the Pacific Island countries that is located along the Great Pacific Ring of Fire and also lies in a belt of intense tectonic activity that experiences high levels of seismicity. It is situated in the region where the Pacific and the Indo – Australian Plate collides which makes it more vulnerable to seismic and volcanic activity in the region. Studies have shown that PNG since 1994 has experiences over 1500 earthquakes which are greater than the magnitude (Mw) of 5, including 20 above Mw of 7. This ranks PNG as the tenth most disaster-prone country in the world and is regularly rattled by earthquakes (Stanaway, 2008). The recent earthquake of magnitude 7.5 in the remote highlands region of PNG (Southern Highlands Province) has claimed the lives of more than 125 people. Majority of whom were killed when their houses were buried by landslide as a result of this earthquake. (Graue, 2021)

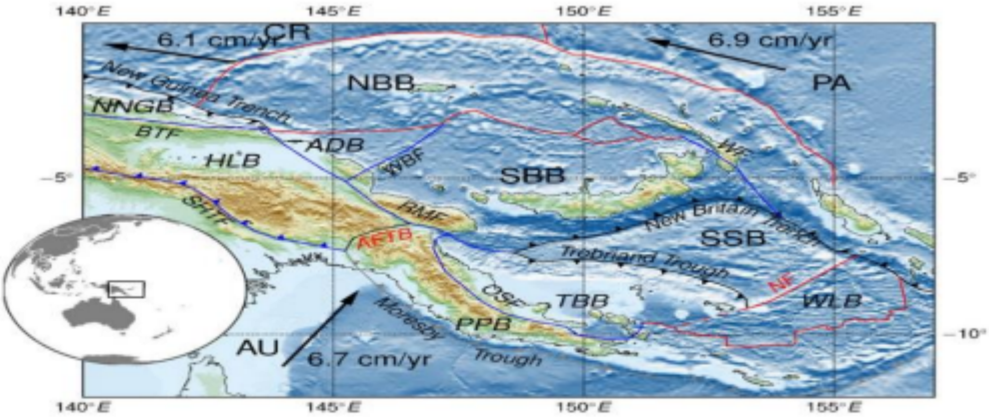

Figure 1. PNG Tectonic map (extracted from Seismotectonic model and probabilistic seismic hazard assessment for Papua New Guinea, Hadi Ghasemi,2020)

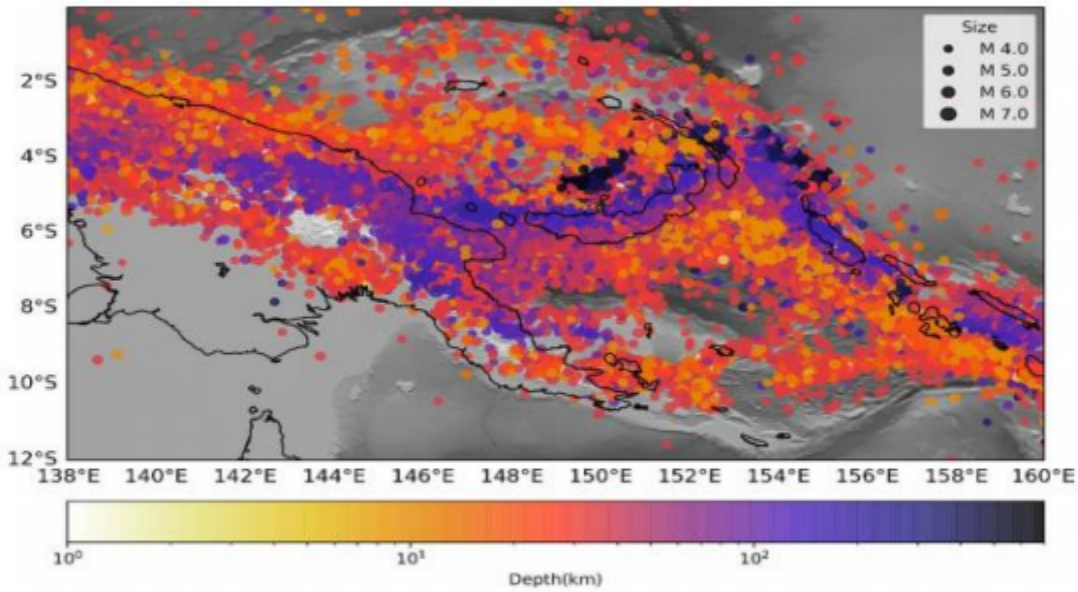

Figure 1. Epicenters from the unified homogenized earthquake catalogue of the PNG region covering the period 1900 to 2017 (extracted from Seismotectonic model and probabilistic seismic hazard assessment for Papua New Guinea, Hadi Ghasemi,2020)

A new seismic hazard model for PNG was produced in 2016, using probabilistic seismic analysis. Hence, the results of the map (refer to figure 3 below) have clearly show a high level of seismic hazard on the Huon Peninsula and in the New Britain. The image shows the area of study (Lae City) is in Zone II of ground acceleration 0.31g (Hadi Ghasemi, 2020).

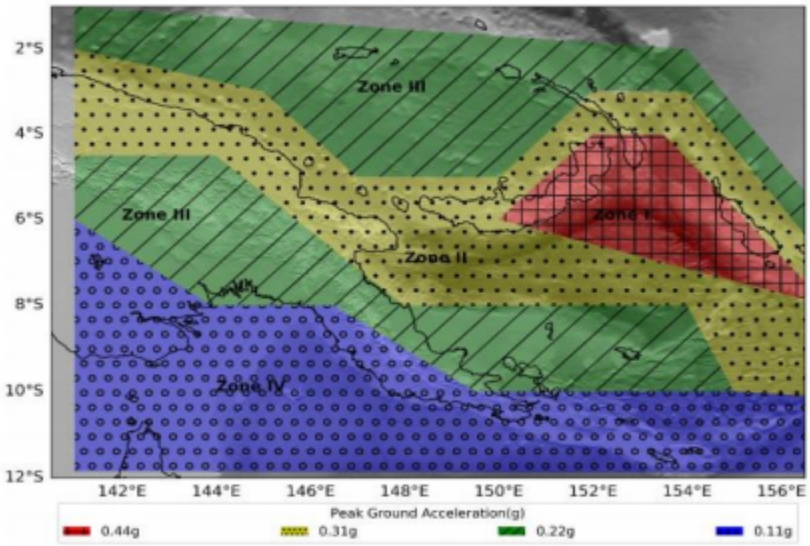

Figure 3. Seismic zoning map of national building code of PNG, the study area (extracted from Seismotectonic model and probabilistic seismic hazard assessment for Papua New Guinea, Hadi Ghasemi,2020)

1.1 International Standards and Building Codes

The standards and building codes of a country will help justify which methodology to use. Using international building codes and standards as a guide can be helpful. However, “international building codes do not usually provide specific recommendations or prescriptions on seismic vulnerability assessment and mitigation” (Dina D’Ayala, 2015). As required the building codes of a country do not deal with the assessment of seismic vulnerabilities of an existing building but rather focus on the seismic design of a new structure. Some building codes and guidelines used are specifically for a project or for a particular geographical area. The Federal Emergency Management Agency (FEMA) provides guidelines, methodologies, and codes to carry out seismic vulnerability assessments specifically for various buildings and projects with respect to 8 their nature (FEMA, 2018).

For this study, we will be utilizing the PNGS 1001-Part 4 in accordance with the FEMA P-155. One of the guidelines it provides is for the seismic vulnerability assessment on high-rise buildings using the RViSTITS android application following the rapid visual screening assessment methods (Riyanto, et al., 2020). Methodologies developed over the years were also based on the guidelines and foundation of FEMA. Thus, FEMA provides a well-organized system needed to carry out seismic vulnerability assessment (Moustafa, Fadzli, & Ehsan , 2020)

1.2 Development of Seismic Vulnerability Assessment Methodologies

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A study conducted by Haryanto Y “Seismic Vulnerability Assessment Using Rapid Visual Screening: Case Study of Educational Facility Buildings of Jenderal Soedirman University, Indonesia” uses an empirical method that verified that the Seismic vulnerability evaluation is an accepted technique for the evaluation of buildings to determine if they are capable of accomplishing specific performance objectives that:

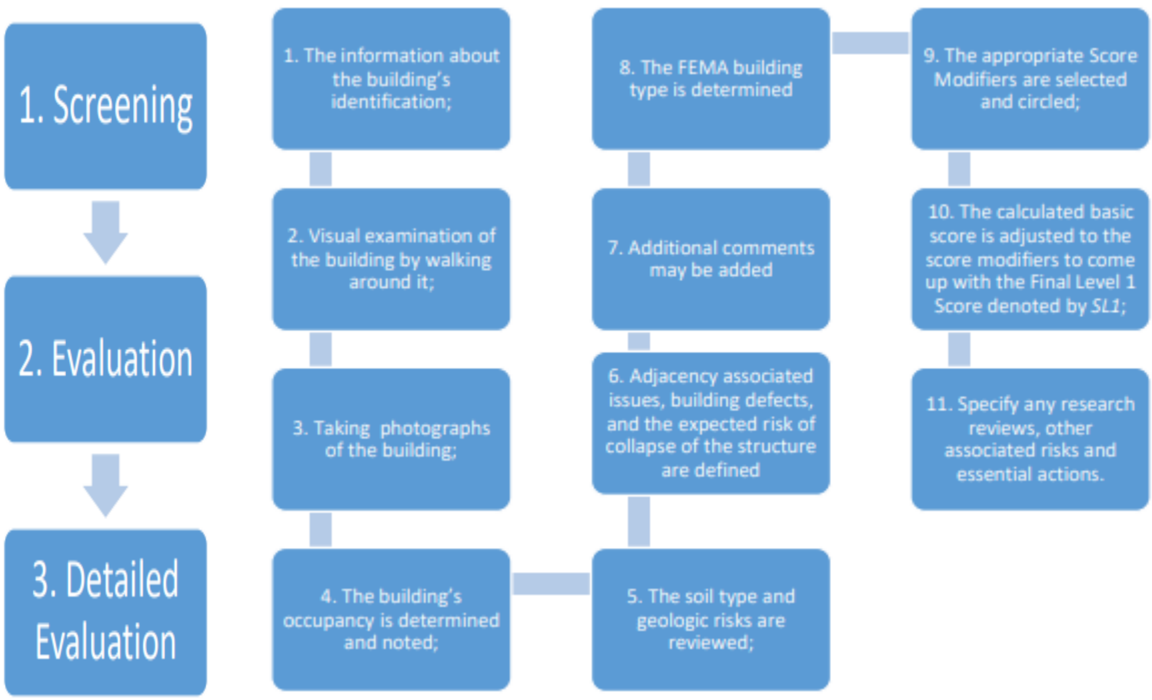
• Identify the tearing and wearing of buildings caused by earthquakes over the years or its condition may decline due to changes of use or the high liquefaction potential of the land.

• Some existing buildings may have been may have not been designed in accordance with the current seismic codes and may not be strong enough to resist the seismic forces. 6 Thus, the results obtained from this seismic evaluation will be used to determine if the building needs repairs or renovation to enhance its resistance against seismic forces or if it needs to be demolished

2 Materials & Methods

Rapid Visual Screening (RVS) is a quick way of assessing the building's vulnerability based on visual inspection. The RVS procedure uses a methodology based on a sidewalk survey of a building and a data collection form, which a person conducting the survey completes, based on visual observation of the building from the exterior, and if possible, the interior.

Rapid Visual Screening Procedure:



(a) (b)

Figure 4. Conceptual Framework : (a) Rapid Visual Screening Procedure (b) Level 1 Data Form Collection Procedure

The level 1 data collection form has six (6) parts to be filled out by the screener:

1. Building Identification
2. Building information
3. Comments
4. Photographs and Sketch Parts
5. Basic Score, Modifiers, and Final Score Parts
6. Extent of Review, Other Hazards and Action Required Parts

In order to fill out this form you will require a copy of the FEMA 154 tables to fully understand and fill in the requirements in the form.

After careful observation of the selected buildings, the evaluator determined the building according to the FEMA Building type. The buildings were identified as below:

1. Building A (Leon Building) – C1, Concrete Moment Resisting Frame Building
2. Building B (Numberwan Super Haus) – C2, Concrete Shear Wall Building
3. Building C (Morobe Haus) – S4, Steel Frame Building with cast in place Shear Walls.
4. Building D (Papindo Shopping Mall) – S4, Steel Frame Building with cast-in-place Shear Wall

Formula for the Basic Score and Score Modifies:

The Final Level Score (S_{L1}) calculated as follows:

$$S_{L1} = Basic\ Score\ \pm Score\ modifiers \quad (1)$$

the tabulated results will be calculated as:

$$S_{L1} = +1.4\ (building\ A), +1.6\ (building\ C), and\ +2(building\ B\ and\ D) \quad (2)$$

The basic score is determined. After the selection of the FEMA building type and the basic score, the score modifiers are identified in order to modify the Basic Score. The Score Modifiers associated with the building's performance attributes give a score that is added to or subtracted from the Basic Score to give the Final Score, denoted by S_{L1}. The value of the Basic Score is ranging from 0 – 7. The Final Score obtained is then compared with the minimum score, which is denoted by S_{min}.

3 Results & Discussion

Lae City is located in Zone 2 where the region is of high seismicity; therefore, the High Seismicity Level 1 data collection form is required. The filling of the form is collected by the evaluator or screening personnel with data collection through visual observation of the building exterior and the interior, if possible.

The visual survey technique was used along with a Data Collection Form (Level 1 Data Collection Form), see the figure below.

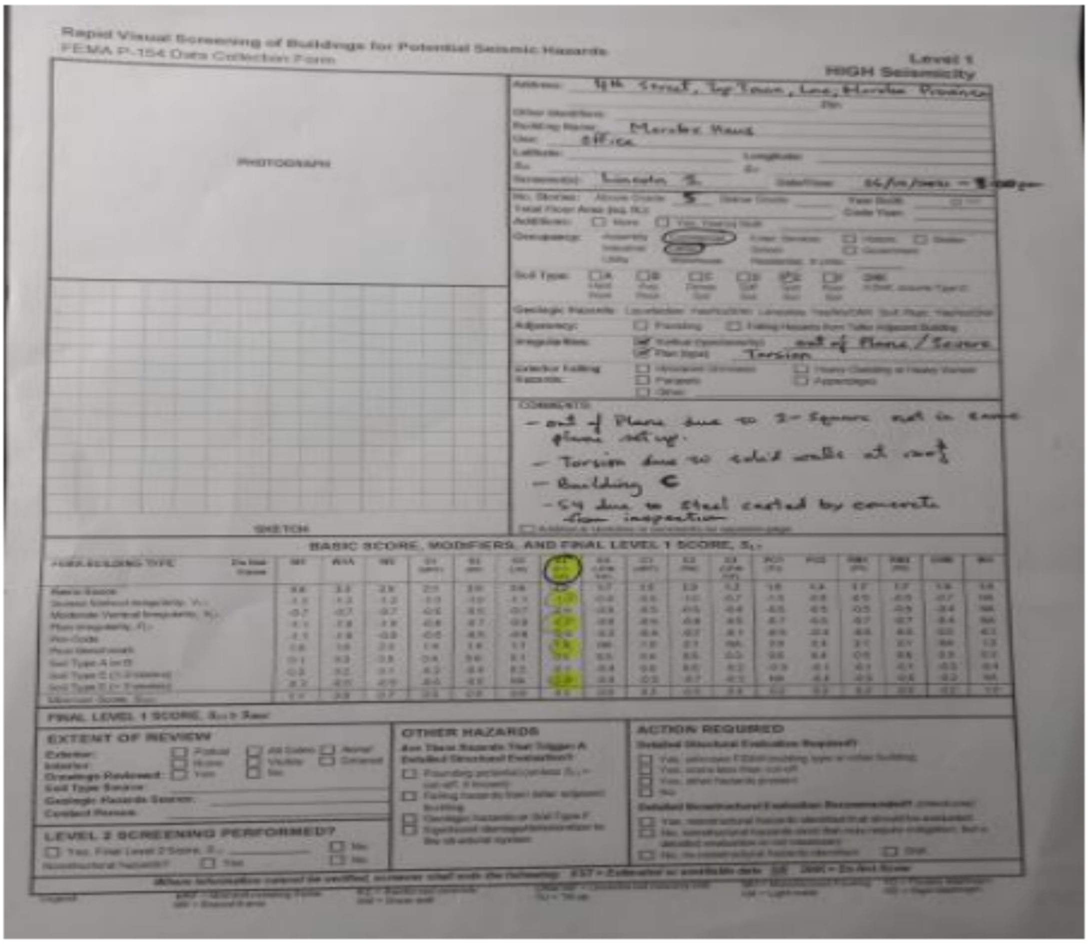

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form
Level 1
HIGH Seismicity
PHOTOGRAPH
SKETCH
BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}
EXTENT OF REVIEW
OTHER HAZARDS
ACTION REQUIRED
LEVEL 2 SCREENING PERFORMED?

Figure 5. Level 1 Data Collection Form used (High Seismicity)

(a) Leon Building

(b) Nambawan Super Haus Buidling

(c) Morobe Haus Building (d) Papindo Shopping Mall

Figure 6. Selected High-Rise Building for Study

Higher final scores imply that the 4 high-rise buildings in Lae City building's probable seismic performance is good and that the buildings are highly resistant to collapse, i.e. when $S_{L1} > S_{min}$ as shown in the table 1 below.

Table 1. Selected High Rise Building RVS

Parameters	**Four Selected High Rise Building in Lae City**			
	A	**B**	**C**	**D**
FEMA BUILDING TYPE	**C1**	**C2**	**S4**	**S4**
Basic Score	**1.5**	**2**	**2**	**2**
Severe Vertical Irregularity, V_{L1}	-0.9	-1	-1	-1
Moderate Vertical Irregularity, V_{L1}	-0.5	-0.6	-0.6	-0.6
Plan Irregularity, P_{L1}	-0.6	-0.8	-0.7	-0.7
Pre-Code	-0.4	-0.7	-0.6	-0.6
Post-Benchmark	1.9	2.1	1.9	1.9
Soil Type A or B	0.4	0.5	0.6	0.6
Soil Type E (1-3 stories)	0	0	-0.1	-0.1
Soil Type E (> 3 stories)	-0.5	-0.7	-0.6	-0.6
Minimum Score, S_{MIN}	0.3	0.3	0.5	0.5
FINAL LEVEL 1 SCORE S_{L1}	**1.4**	**2**	**1.6**	**2**

4 Conclusion

Overall, these scores indicate the probability of collapse of the building in the event that it experiences ground motions equal to or greater in magnitude than the maximum considered earthquake-targeted risk. From the calculations, $SL1 > Smin$, for the four high rise building in evaluated. This clearly indicates that the building seismic performance is good and is highly resistant to collapse.

5 References

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