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Evaluation of Building Vulnerability to Earthquake Using Rapid Visual Screening (RVS) Method

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Abstract. Indonesia is one of the countries prone to earthquakes. One of the earthquake disasters that occurred several years ago hit Palu and Donggala on September 28, 2018. It caused severe damage to infrastructure. Therefore, it is necessary to evaluate buildings vulnerable to earthquakes as a form of prevention. One of the buildings in Jember, the dr. Soebandi hospital, experienced cracks in the walls during an earthquake measuring 6.0 on the Richter scale in Nusa Dua Bali on July 16, 2019. This study carried out the risk assessment of the vulnerability of buildings to earthquakes using the Rapid Visual Screening (RVS) method from FEMA P-154. RVS is a method to identify a building that is potentially vulnerable to earthquake hazards based on visual observations from the exterior and interior of the building. The results of the evaluation using the RVS method showed that the dr. Soebandi hospital is categorized as safe and not prone to earthquakes, with a potential vulnerability percentage of 0.0126%. Based on these results, the building does not require special treatment to anticipate earthquakes; however, maintaining the occupants' safety and extending the building's life requires routine maintenance.

Keywords: earthquake, vulnerability, rapid visual screening, assessment, maintenance

INTRODUCTION

Indonesia is prone to earthquakes because Indonesia is an area where three tectonic plates meet, namely the Eurasian plate, the Indo-Australian plate, and the Pacific plate [1]. One of the earthquake disasters that occurred several years ago was the earthquake that happened in Palu and Donggala on September 28, 2018. According to data from the National Disaster Management Agency (BNPB), the Palu and Donggala earthquakes caused damage to 68,451 houses, 327 houses of worship, 265 schools, 78 office buildings, 362 shops, seven bridges, 168 road cracks, and so on [2]. It shows that only few planned infrastructures are earthquake resistant, and there is a lack of data on buildings prone to earthquakes. Therefore, it is necessary to evaluate buildings that are vulnerable to earthquakes as a form of prevention.

Many studies anticipate the collapse of infrastructure. Based on the literature and previous researchers, research on construction reliability can be done technically and in detail. Visually to support the initial assessment/screening of infrastructure that requires further handling have done. The study of material failure analysis by testing the relationship between steel and concrete materials has been carried out [3]. Research of the train speed limitation due to the vibration of the steel bridge construction to keep the structure from collapsing has also been carried out [4]. Analysis of building reliability uses the technical procedure for guidelines for the certificate of eligibility for the function of buildings regulation of the minister of public work to maintain structural reliability values [5] and inspections to interpret building reliability [6]. Research on the resistance of steel buildings to earthquakes uses a Fuzzy-TOPSIS method to make priority decisions based on the level of damage [7]. In addition, structural performance analysis using FEMA P-58 was carried out [8]. However, these studies require a lot of resources and require time in decision-making. Therefore, in this study, a visual observation method was developed to accelerate the screening of buildings that need immediate handling and are still safe from earthquakes.

Jember is one of the cities in East Java Province, located at coordinates $7^0$14'35" East Longitude and $8^0$33'56" South Latitude. According to SNI 1727-2002 concerning Standards of Earthquake Resistance Planning for Building Structures, the City of Jember is included in earthquake zone 3 (moderate seismic zone). There are many high-rise buildings in Jember, and the dr Soebandi hospital is one of the oldest hospitals in Jember Regency. The dr Soebandi hospital experienced a crack in the wall during an earthquake measuring 6.0 on the Richter scale in Nusa Dua Bali on July 16, 2019. Although there was no severe damage, it caused approximately four rooms to suffer minor damage, and the patients inside became concerned about the safety of the building. Building construction is considered safe if the building can stand firm until the planned deadline. However, many buildings still do not pay attention to their vulnerability to earthquakes, which can cause huge losses and even fatalities.

Based on the reasons above, it is necessary to evaluate the building to anticipate building vulnerability to earthquakes. The risk assessment of the vulnerability of buildings to earthquakes can be carried out using several methods such as Rapid Visual Screening (RVS) from the Federal Emergency Management Agency (FEMA) and ASCE 41-13 from the American Society of Civil Engineering (ASCE). This present study uses Rapid Visual Screening (RVS), more commonly applied than the ASCE 41-13 method. According to the FEMA Standard P-154 [9] that Rapid Visual Screening (RVS) is a method to identify a building that is potentially vulnerable to earthquake hazards based on visual observations from the exterior and interior of the building if possible. The RVS method was published by the Federal Emergency Management Agency (FEMA) in March 2002 under the title Rapid Visual Screening of Buildings for Potential Seismic Hazards 2nd edition and further updated in January 2015 entitled Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook 3rd edition. There are several differences between the old RVS form and the new RVS form; among others, there are several additional identifications in the latest RVS form, namely the extent of the review or the period. The assessment and action were required, or further steps were needed.

This research applies the Rapid Visual Screening (RVS) method from FEMA P-154 for buildings in Indonesia with earthquake zone D or high earthquake zones such as Jember. It has adapted to earthquake zones in Indonesia which refers to SNI 1726-2019 regarding planning procedures. Earthquake resistance for building and non-building structures. It has the aim that the Rapid Visual Screening (RVS) method of FEMA P-154 can be applied or used as a parameter to evaluate the vulnerability of buildings to earthquakes by Indonesian regulations. Several previous researchers have applied the Rapid Visual Screening (RVS) method to assess earthquake buildings' vulnerability. They are government building assessments in Pekanbaru, Riau [1], cultural heritage houses in Yogyakarta [10], and the CDAST building at the University of Jember [11]. Evaluation of structure performance using FEMA and pushover analysis [12]. RVS can also be applied to detect potential ground movement [13]. RVS which investigates vulnerability due to earthquakes using smartphones has also been developed [14]. The results of some of these studies stated that the buildings reviewed were not susceptible to earthquakes. Previous studies still used the RVS form from FEMA 154 in 2002, and the form used in this study is the RVS form from FEMA P-154 in 2015 and; this present study also identifies the risk of danger from non-structural elements due to earthquakes utilizing the form from FEMA E-74 year 2011.

Based on the above background, the building's vulnerability evaluation to earthquakes using the Rapid Visual Screening (RVS) method applied to a case study of the building dr. Soebandi Jember. So the vulnerability building to earthquakes or safe against earthquakes can be known.

METHODOLOGY

This research was implemented on dr Soebandi Hospital, Jember located on Jalan dr Soebandi No. 124 Jember Regency. The qualitative analysis was used in this study by collecting data about the dr Soebandi Hospital's occupancy, master plan drawings, land data, and earthquake zoning maps supporting the rapid visual screening assessment.

This research used the literature study by collecting theories from several literature sources related to the research to be taken, such as e-books and scientific journals that served as references in this research. The regulations used in this research consisted of FEMA P-154 2015 [9] entitled Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook third edition and SNI 1726-2019 procedures for planning earthquake resistance for structures buildings and non-buildings.

The data collection process included these following activities:

a. Designing pre-site
b. Determining and reviewing RVS form
c. Implementing of screening in the site

RESULT AND DISCUSSION

Based on the location coordinates building seen in Design Spectra Indonesia from the official page rsa.ciptakarya.pu.go.id, the value of the spectral acceleration in the short period, the 5% attenuation (S_{DS}) of 0.67 g, and the value of the spectral acceleration in one second, the attenuation 5% (S_{D1}) of 0.49 g, for more details can be seen in Figure 1. Therefore, based on SNI 1726-2019 regarding procedures for planning earthquake resistance for building and non-building structures, Jember is in the risk category D or high earthquake zone.

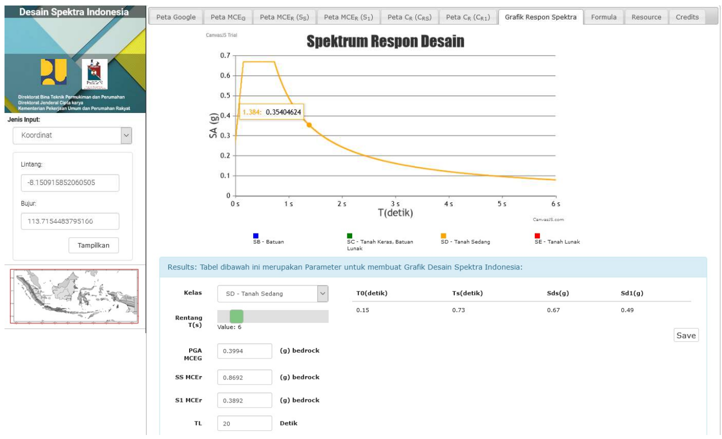

FIGURE. 1. Spectral acceleration

TABLE 1. Seismic design categories based on short-period acceleration response parameters

Value of S_{DS}	Risk Category	
	I or II or III	IV
$S_{DS} < 0.167$	A	A
$0.167 \leq S_{DS} < 0.33$	B	C
$0.33 \leq S_{DS} < 0.50$	C	D
$0.50 \leq S_{DS}$	D	D

(Source: SNI 1726-2019)

TABLE 2. Seismic design categories based on acceleration response parameters over one second

Value of S_{D1}	Risk Category	
	I or II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 \leq S_{D1} < 0.133$	B	C
$0.133 \leq S_{D1} < 0.20$	C	D
$0.20 \leq S_{D1}$	D	D

(Source: SNI 1726-2019)

Depending on the earthquake zone map in SNI 1726-2019, the value of the acceleration of the short-period MCE spectral response, 5% attenuation (S_S) between 0.8 – 0.9 g (Figure 2). While the value of the acceleration of the MCE spectral response in one second, the attenuation of 5% (S_1) is between 0.3 – 0.4 g (Figure 3). After checking the Indonesian Spectra Design, the values obtained are S_S = 0.8692 g and S_1 = 0.3892 g. So based on FEMA P-154, Jember is categorized as a moderately high seismic area; for more details, see Table 3.

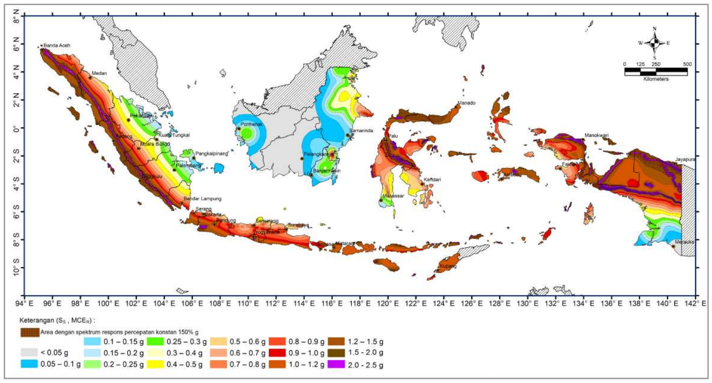

FIGURE 2. Earthquake zone map based on short-period MCE spectral response acceleration

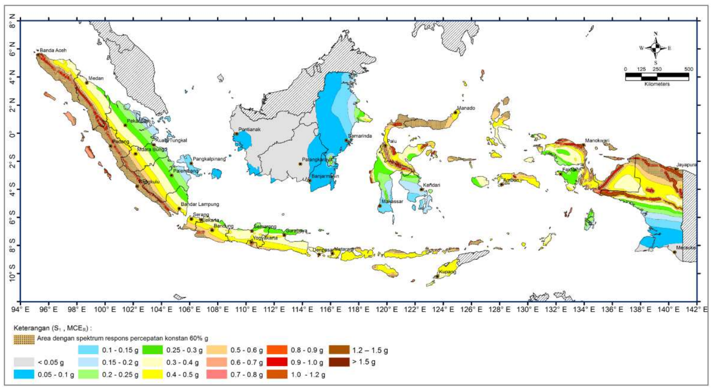

FIGURE 3. Earthquake zone map based on the acceleration of the MCE spectral response for one second period

TABLE 3. Spectrum response value

Seismicity Location	Response Spectrum Acceleration /S_S (Short Period /0.2 second)	Response Spectrum Acceleration /S_1 (Long Period /1 second)
Low	$S_S \leq 0.25g$	$S_1 \leq 0.10g$
Moderate	$0.25g \leq S_S \leq 0.50g$	$0.10g \leq S_1 \leq 0.20g$
Rather High	$0.50g \leq S_S \leq 1.00g$	$0.20g \leq S_1 \leq 0.40g$
High	$1.00g \leq S_S \leq 1.50g$	$0.40g \leq S_1 \leq 0.60g$
Very High	$S_S \geq 1.50g$	$S_1 \geq 0.60g$

(Source: FEMA P-154. 2015)

RVS FORM ANALYSIS LEVEL 1

a. Building Information Identification

The building to be identified is the Regional Hospital Building, dr Soebandi Jember, which is on Jalan dr Soebandi No. 124 Jember Regency. The use column is the building utilizing, namely as a hospital, the first and second floors are used as poly services, while the third floor is offices and administration. This building has the coordinates -8.150915852 South Latitude and 113.7154483 East Longitude. According to the Indonesian Spectra Design, the building has a spectrum response value of S_S = 0.8692 g and S_1 = 0.3892 g.

b. Building Characteristic

The dr Soebandi hospital is a building with a reinforced concrete structure model, totaling three floors and having a basement that is not too wide (approximately 1/3 of the building area) used for parking lots. The building was built in 2005 and underwent renovation and the addition of a third-floor building in 2013.

c. Picture and Sketch of Building

The picture of the dr Soebandi hospital (see Figure 5) and a sketch of the dr Soebandi hospital can be seen on Figure 6).

FIGURE 5. The front view of dr Soebandi's building

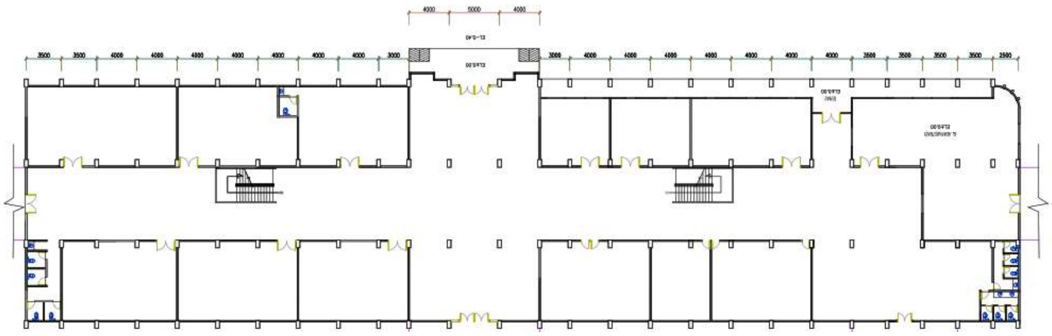

FIGURE 6. The floor plan of dr Soebandi's building (Source: Documentation of RSD dr. Soebandi)

d. Type of Dwelling Building

Hospital building dr Soebandi is included in the category of emergency services because the hospital is a health service institution that concerns with the safety and health of patients. In addition, there is an emergency room or emergency room that provides 24-hour service to patients who need it at any time.

e. Type of Soil

The soil type of dr Soebandi hospital is not known because the hospital does not keep the data archive. On the book FEMA P-154 [11], the form was filled with DNK (don't know), and it was assumed as soil type D, the medium soil type.

f. Geological Hazard

Based on the identification, there are no geological hazards such as liquefaction, landslides, or cracked soil around the dr Soebandi.

g. Closeness

Based on the identification results, the dr Soebandi is adjacent to a new building that is still a concrete frame structure behind the dr. Soebandi hospital. The distance between the two buildings is 1.87m (see Figure 7). The new facility has approximately the same height as the building under review. Based on the FEMA P-154 (2015) book, the danger caused by this adjacency can be in the form of a collision when an earthquake occurs or can cause a fall hazard. The minimum distance between the two buildings is 1" per floor for a relatively high earthquake area. Therefore, the adjacency column does not need to be filled or left blank.

FIGURE 7. The distance between dr Soebandi's hospital with the new building is 1.87 m

h. Building irregularity

At the hospital building, dr Soebandi, there is no vertical or horizontal irregularity plan in the building structure. Each floor of the building has a typical design, or the construction of the first, second, and third floors is the same. In addition, the planning of the building is only rectangular, not in the form of the letter E, L, T, U, also +.

i. Exterior falling hazard

Exterior hazards in terms of non-structural potential to fall on the dr Soebandi hospital is an outdoors fan. Almost every room in the building uses an air conditioner (AC); there are many outdoor on the exterior side of the building (see Figure 8).

j. Final Score Assessment

To get the final score assessment, fill the values in the base score column, modifier, and level 1 final score (SL-1). This column assesses that not all variables matter because several analysis results do not match those in that column. The final score obtained on the level 1 form assessment is as follows (see Tabel 4).

TABLE 4. Final Score on Form level 1

Variable	*Score*
Building type	C1
Basic score	1.7
Pos-Benchmark	1.9
Minimum score	0.3
Final score	**3.9**

FIGURE 8. The exterior view that could potentially cause a fall hazard

The final score assessment at the dr Soebandi hospital above obtained a final score of 3.9>2. So, according to the book Rapid Visual Screening from FEMA P-154 (2015), the building can be categorized as safe and has no potential for collapse in the event of an earthquake. And because the analysis using the level 2 form is a building with a final score of 2, the RSD dr Soebandi did not require a more detailed evaluation on the level 2 form.

1. Vulnerability of The Hospital Building dr Soebandi

After obtaining the final score, then an analysis was carried out to determine the percentage of the potential vulnerability of a building with the following formula:

$$\text{Vulnerability potential} = \frac{1}{10^S} \times 100\% \quad (1)$$

Where S is the final score obtained from Table 4, Table 5 shows the percentage value of the potential vulnerability of the RSD dr Soebandi.

TABLE 5. Result of the percentage of the potential vulnerability of the building

Category	Note
Building	dr Soebandi
Building Type	C1
Final Score (*SL1*)	3.9
Potential Vulnerability (%)	0.0126

Based on the above, the final score of 3.9 (>2) and the level of vulnerability of the dr Soebandi hospital by 0.0126%. Therefore, no particular action is required to anticipate the hazard of an earthquake. However, the building requires periodic maintenance and regular maintenance by maintaining the reliability of the building and its facilities and infrastructure so that the building is always functional [15]. The aim is to extend the life of the building and to ensure the safety of the building's users.

2. Non-Structural Component Hazard

This study carried out a hazard analysis of non-structural components of dr Soebandi hospital using the FEMA E-74 reference in 2011. According to FEMA E-74 (2011), the purpose of this non-structural component hazard analysis is to identify non-structural components that may be vulnerable to earthquake damage. In this analysis, the author uses three forms, namely, prioritized non-structural inventory forms, non-structural seismic hazard, and non-structural seismic risk levels.

1. Non-structural inventory

This non-structural inventory aims to identify non-structural components that are less qualified and dangerous. Based on FEMA E-74 (2011), the non-structural component identification form has three risk categories such as:

a. Life safety (LS): the risk gets injuries due to objects.
b. Property loss (PL): raises the risk of incurring repair or replacement costs due to the damaged object; and
c. Functional loss (FL): not functioning due to damage, impacting the building component operation failure.

The types of details have three categories including:

a. Non-Engineered (NE), i.e., the repair without requiring an engineer,
b. Prescriptive (PR), i.e., an engineer conducted repair/maintenance and not depending on the damage; and
c. Engineering Required (ER), i.e., the job requires an engineer in repair/maintenance.

In this form, there is also a description column to identify the problems. That has observed hazards and made the suggestions. The following is the result of prioritized non-structural inventory analysis (see Table 6).

TABLE 6. Non-structural inventory analysis results

INVENTORY PRIORITY									
No	Description	Location	Sum	unit	LS	PL	LF	Detail	Note
					"H","M",or"L"			NE, PR, ER	
1	Void guard	Floor 2 and Floor 3	6	unit	H	H	M	PR	The void trellises are maintained periodically in terms of bolting on unreinforced walls/parapets so that they do not collapse/fall.
2	Plafond interior	Corridor Floor 2	1	set	H	M	L	ER	There is damage to the ceiling that has the potential to fall. It must be repaired immediately to

INVENTORY PRIORITY									
No	Description	Location	Sum	unit	LS	PL	LF	Detail	Note
					"H","M",or"L"			NE, PR, ER	
									reduce further damage that can endanger the occupants below
3	List Ceiling	Corridor Floor 3	1	set	M	M	L	ER	There is a ceiling trim that can fall because it is not attached to the ceiling. It must be repaired immediately to reduce further damage
4	Plafond exterior	In front exterior	1	set	M	M	L	ER	There is an exterior ceiling that has fallen or has holes. It must be repaired immediately to reduce further damage
5	Electricity network system	Corridor Floor 2	1	set	M	M	H	ER	The network system must be improved and further tidied up to minimize the occurrence of short circuits
6	Oxygen cylinders	Corridor Floor 1	>10	unit	L	M	M	NE	Oxygen cylinders must be tied with a chain or made a special place for its placement. It can minimize the occurrence of falls that could potentially explode.
7	Cabinet	Corridor Floor 3	1	unit	L	L	L	NE	The anchored cabinets to the structure's walls prevent difficulty in the evacuation during an earthquake.
8	Shoe Rack	IBS (Central surgical installation) 2nd floor	2	set	L	L	L	NE	Shoe racks must be anchored to the walls of the structure to prevent difficult evacuation during an earthquake.
9	The fan/blower attached to the wall	Floor 1 and 2	10	unit	M	M	L	NE	The fan/blower attached to the wall is frequently investigated so that it does not collapse or fall, which can endanger the occupants below it.

Based on the analysis results, several components have priority, and some have a level of danger because they do not meet the requirements. One of the examples of the importance is void trellises on the 2nd and 3rd floors, with a high occupant safety risk (LS) value (H) and injury to death for the occupants below. Besides that, it can also cause damage to other properties, so the value of the risk of property damage (PL) is high (H). The risk of the item not functioning when it falls is of moderate weight (M) because the trellis only serves as a decoration on the void. The type of details of the void trellis is included in the prescriptive (PR) because engineers and non-engineered can carry out the maintenance. So the suggestion from the writer is that the maintenance and care of the void trellis must be carried out routinely in terms of the strength of the bolts on the wall or parapet so that the frame does not fall.

2. Non-structural Seismic Hazard

This non-structural seismic hazard identification aims to assess whether structural components (architectural, mechanical, electrical, and plumbing (MEP), furniture, fixtures, and equipment (FF&E), or other contents) are potentially hazardous to building occupants or are likely to cause a financial loss on the earthquake event. In this form, the components and list of questions reviewed are adjusted to the existing structure in FEMA E-74 in 2011 so that some elements have no in the building review. Table 7 shows an example of the non-structural seismic hazard analysis results of the RSD dr Soebandi.

Several components are compliant, inappropriate, or not known (non-compliance), and some do not apply to the provided questions. As in the example of the pipe component above, it has been laterally restrained/has been anchored to the structure, so the assessment in column C (compliance) mark with a tick (√). Another example is the emergency exit component. The shatter-resistant glass does not have cover in the mirror above the exit door, so a checkmark sign on the NC (non-compliance) column. And the following example is the escalator component that is not installed in the dr Soebandi hospital so that the assessment gives a tick in the NA column (not applicable).

TABLE 7. Non-structural seismic hazard analysis (for example)

No	Component Name	Main Problem	Picture	C	NC	NA	Check List Question (C=Yes; NC=No or not known; NA=Not Available)
1	**Architecture component**						
1.1	Exterior wall component						Falling hazard from outside is the primary concern, especially items that lie above 10 feet and objects that may fall from exits, walkways, and sidewalks
	Exterior wall (with an adhesive)	Fall hazard		✓			Is the exterior wall sufficiently adherent to the structure? [This includes a relatively thin layer of tile, masonry, stone, terra cotta, ceramic tile, glass mosaic units, stucco, or similar materials that are attached to walls or structural frames using adhesives].
				✓			Based on visual observations, are the veneers free of cracked or loose parts that may have fallen during the earthquake?
1.2	And so on.	…					

3. Rate of Seismic Risk non-structural

In identifying the level of non-structural seismic risk, the form used is almost the same as the non-structural inventory form; only the risk category is assessed based on the vibration intensity. The vibration intensity map (if any) or the earthquake zone map can determine the estimated vibration intensity. Because earthquakes that occur in areas with high earthquake zones do not always have a high power of movement and are likely to experience low and moderate vibrations, the intensity of vibration used is low, medium, and high intensity. For more details, see an example of the level of non-structural seismic risk in Table 8.

Based on Table 8, there are several components which when the vibration intensity is high, these components have a high-risk assessment (H) in the three categories, such as LS, PL, and FL. The components are ceiling components, stairs, power lines, and traction lifts and their members. In addition, when the vibration intensity is moderate, some of these components still have relatively high (H) and medium (M) risks, such as glass components, ceilings, roof tiles, stairs, electrical control panels, and their channels, as well as traction, lifts along with its members. Therefore, according to the study, it must pay more attention to components that has moderate vibration intensity which has a relatively high or medium risk value to maintenance and care. This evaluation intends that these components remain strong and ready in the event of an earthquake at any time.

TABLE 8. Non-structural seismic risk level (for example)

No.	Name	Shaking Intensity (L; M; H)	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
1	**Architecture component**					
1.1	**Exterior wall**					
	Exterior wall (with an adhesive)	High	H	M	L	
		Moderate	M	L	L	ER
		Low	L	L	L	
	Exterior glass wall system	High	H	H	L	ER

No.	Name	Shaking Intensity (L; M; H)	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		Moderate	M	M	L	
		Low	M	L	L	
	Glass or windows on the roof	High	H	M	L	
		Moderate	H	L	L	ER
		Low	M	L	L	
1.2	And so on					

CONCLUSION

This study has evaluated the dr. Soebandi building using The FEMA P-154 (2015), the final score assessment was 3.9 (> 2), so the building is categorized as safe and not prone to earthquakes. Based on the final score assessment and equation 1, this study calculated the potential vulnerability of building using equation one. The possible exposure percentage of the building is 0.0126% or the possibility of collapsing due to an earthquake of 0.0126%.

Based on the results of the final score and the percentage of potential vulnerability in the dr. Soebandi building, no particular action is required to anticipate the danger of an earthquake. However, the regular and periodic maintenance of the building must act to maintain occupants' safety and extend the life of the building. For the care and maintenance of non-structural components, you can see the results of the hazard analysis of non-structural components on the non-structural inventory priority form and the level of non-structural seismic risk.

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