Original Article

e-ISSN: 2581-0545 - https://journal.itera.ac.id/index.php/jsat/

Received 17th January 2024
Accepted 22nd June 2024
Published 30th June 2024

Open Access

DOI: 10.35472/jsat.v8i1.1719

Estimation of Earthquake Insurance Premium by Considering Earthquake Probability and The Damage Ratio of Buildings in Banda Aceh and Sibolga City

Kania Fatin Afifah, Fuji Lestari*, Florencia Brigitta

Program Studi Sains Aktuaria, Fakultas Sains, Institut Teknologi Sumatera

** Corresponding E-mail: fuji.lestari@at.itera.ac.id*

Abstract: Indonesia is one of the countries prone to earthquakes with significant damage. An area that is frequently hit by earthquakes is Sumatra Island. Several cities, such as Banda Aceh City and Sibolga City on Sumatra Island, quite often experience tremors. For this reason, mitigation efforts are needed through earthquake insurance in managing disaster risk in earthquake-prone areas such as Banda Aceh City and Sibolga City so that it can reduce the impact caused by earthquake disasters. This research aims to determine the probability of an earthquake occurring in Banda Aceh City and Sibolga City using the Probabilistic Seismic Hazard Analysis (PSHA) method. Apart from that, this research also aims to determine the value of the building damage ratio and the estimated value of pure earthquake insurance premiums in Banda Aceh City and Sibolga City. The analysis results show that the estimated pure premium value for residential commercial and industrial building types with less than nine floors in Banda Aceh City is around 2.96 and 21.03 times greater than that of Sibolga City. Meanwhile, the estimated pure premium value for commercial and industrial building types with more than nine floors in Banda Aceh City is more minor, around 6.42 times, compared to Sibolga City.

Keywords: *earthquake insurance; probabilistic seismic hazard analysis; ground motion model; rate of occurrence of earthquakes; damage ratio of buildings*

Introduction

Indonesia is one of the countries frequently hit by earthquakes because geographically, Indonesia is traversed by the confluence of four tectonic plates, namely: the Eurasian plate, the Indo-Australian plate, the Philippine Sea plate, and the Pacific plate [1]. Apart from that, Indonesia is also located in the Ring of Fire or the Pacific Ring of Fire, which makes Indonesia one of the countries prone to earthquake disasters in the world [2]. Based on records from the Geological Agency, from 2000 to 2021, there have been 5 to 26 destructive earthquakes in Indonesia, meaning that these earthquakes have resulted in casualties, building damage, environmental damage, and property loss. Strong earthquakes can also cause major damage to buildings and cause loss of life [3].

One of the worst earthquake disasters in Indonesia occurred in 2004 in Banda Aceh, with a magnitude scale of $M_w = 9{,}2$, accompanied by a tsunami [4]. The earthquake event resulted in many fatalities and injuries, material losses, and damage to regional infrastructure and the environment, which affected the economic and development sectors. The earthquake disaster in Banda Aceh City could have occurred due to the geological conditions of the Aceh Province region, which is located at the meeting of two plates, namely the Eurasian plate and the Indo-Australian plate, which is traversed by the Sumatran fault system with active structures in it [5]. Apart from Banda Aceh City, Sibolga City is also one of the cities prone to earthquakes due to the geological condition of Sibolga City, which is traversed by active fault lines and subduction activities. Efforts are needed to control risks due to earthquakes by involving the insurance industry's role. The type of insurance that can protect against the risk of natural disasters or earthquakes is general insurance with a special product in the form of earthquake insurance. According to SE OJK Number 6/SEOJK.05/2017, earthquake insurance is an insurance product that protects property according to the wording of the Indonesian Earthquake Insurance Standard Policy (PSAGBI).

In earthquake insurance, premium rates must be calculated properly so the insurance company can avoid losses or bankruptcy. The premium rate can be determined by considering the chances of an earthquake occurring using seismic hazard analysis with a probabilistic approach or what is known as Probabilistic Seismic Hazard Analysis (PSHA). The building damage ratio also needs to be considered when determining premium rates for earthquake insurance products. This is supported by the research conducted by [6], which shows that calculating earthquake insurance premium rates requires integrating information about the vulnerability and danger of future earthquakes by considering various levels of earthquake danger.

Based on the description of the problem and previous research, it can be stated that this research aims to determine how much the estimated earthquake insurance premium rate is by taking into account the probability of an earthquake and the ratio of building damage in Banda Aceh City and Sibolga City. This research uses secondary data in the form of historical data on earthquake events and data on building damage in Aceh Province and North Sumatra Province. The method used in this research is quantitative, where earthquake event data is analyzed using Probabilistic Seismic Hazard Analysis (PSHA) while building damage data is analyzed using damage ratio values.

Methods

Seismic Hazard

Seismic hazards are dangers caused by earthquakes, which arise due to the shaking of the earth's surface due to the release of accumulated energy produced by the movement of tectonic plates in the earth's crust [7]. Seismic hazard analysis estimates the danger of ground shaking due to earthquakes at a particular location. The aim is to develop earthquake-resistant building designs and assess the safety of important buildings such as dams, nuclear power plants, bridges, high-rise buildings, etc. [8]. Generally, there are two approaches to analyzing seismic hazards in an area. These approaches are Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA).

The probabilistic approach to seismic hazard analysis involves integrating the probability of occurrence of a certain level of selected strong motion parameters due to the total seismicity expected to occur in an area around a radius of 300 km from the selected location during a certain period [9]. In the probabilistic approach, all possible earthquake events and the resulting level of ground movement will be considered, along with the probability of occurrence of the earthquake event, to obtain a level of ground movement intensity that exceeds a tolerable level [10]. Probabilistic seismic hazard analysis (PSHA) is used to estimate seismic hazards based on the worst scenario by adding scenarios that consider factors into account.

Uncertainty factors in PSHA include magnitude, location, and time and frequency of earthquake events. Each uncertainty factor is analyzed separately, and the results obtained are combined using the total probability theorem. From this combination, the following equation is obtained:

$$\lambda(IM > x) = \sum_{i=1}^{n_{sumber}} \lambda(M_i > m_{min}) \int_{m_{min}}^{m_{max}} \int_0^{r_{max}} P(IM > x|m, r)\, f_{M_i}(m)\, f_{R_i}(r)\, dr\, dm \qquad (1)$$

With:

$\lambda(IM > x)$: annual earthquake occurrence rate with $IM > x$,

$\lambda(M > m_{min})$: annual earthquake occurrence rate with magnitude (M) greater than m_{min},

$P(IM > x|m, r)$: the probability that IM exceeds x at a location with certain magnitude (m) and distance (r) values,

$f_M(m)$: probability density function of magnitude,

$f_R(r)$: probability density function of distance,

n_{sumber} : number of earthquake sources,

M_i : magnitude at the source i,

R_i : distance to source i,

m_{min} : minimum earthquake magnitude,

m_{max} : the maximum earthquake magnitude that can be produced by an earthquake source, and

r_{max} : maximum distance.

Damage Ratio

Damage Ratio (DR) is defined as the ratio of the cost of repairing damage caused by an earthquake to the cost of replacing the building. One damage ratio value is assigned to each damage state (DS) or damage status, referred to as the central damage ratio (CDR). CDR describes the best-estimated damage ratio at each damage status. According to [11] estimates the value of damage ratio and central damage ratio according to various damage (**Table 1**).

Table 1. Damage Ratio and Central Damage Ratio Values at Different Damage Status

Damage Status	Damage Ratio (%)	Central Damage Ratio (%)
Light Damage	1-10	5
Moderate Damage	10-50	30
Heavy Damage/Collapsed	50-90	70

Damage Probability Matrix

The Damage Probability Matrix (DPM) is a popular tool for estimating future losses caused by earthquakes and is widely used to estimate the potential liability of insurance companies [12]. DPM displays the probability distribution of damage to the same type of building with different damage states (DS) at a specified earthquake intensity (I) [6]. Based on available post-earthquake damage data, DPM can be formulated as follows:

$$\boldsymbol{P_k(DS, I) = \frac{N(DS, I)}{N(I)}} \quad (2)$$

Where $P_k(DS, I)$ is the probability of DS observed in the kth type building when exposed to earthquake intensity I, $N(DS, I)$ is the number of k-th type buildings in DS damaged condition and when exposed to earthquake intensity I, and $N(I)$is the total number of type k buildings when exposed to earthquake intensity I. The general form of the damage probability matrix (DPM) (**Table 2**).

Table 2. *Damage Probability Matrix* (DPM)

Damage Status	Center Damage Ratio (%)	Intensity				
		V	VI	VII	VIII	IX
Light damaged	5	Damage Status Probability $P_k(DS, I)$				
Moderate damaged	30					
Heavy damaged/collapsed	85					

The damage distribution corresponding to each intensity level can be expressed by one parameter called the mean damage ratio (MDR) and is shown in the following equation:

$$\boldsymbol{MDR_k(I) = \sum_{DS} P_k(DS, I) \times CDR_{DS}} \quad (3)$$

In the following Equation, $P_k(DS, I)$ represents the damage status probability, and CDR_{DS} represents the central damage ratio. The combination of seismic hazard and average damage ratio is the sum of the simple multiplication of SH and MDR at different earthquake intensities, as shown in Equation (4), where $EADR_k$ represents the expected annual damage ratio of building type k.

$$\boldsymbol{EADR_k = \sum_{I} MDR_k(I) \times SH_I} \quad (4)$$

$EADR_k$ describes the insurance rate percentage of the replacement cost of the property unit [6]. Meanwhile, SH_I is the probability of an earthquake occurring, which is obtained from the annual earthquake occurrence rate $(\lambda(IM > x))$.

Premium

The price charged by the insurance company to transfer the risk of loss from the insured to the insurer is called the insurance premium. Premiums are the primary source of funds used for the business operations of an insurance company. In each period, insurance companies must determine the appropriate premium amount to charge users of their services [13]. The premium charged must be commensurate with the potential losses that may occur. Therefore, proper risk measurement is essential for determining insurance premiums.

In the insurance and reinsurance industry, specifically in the general insurance industry, the number of claims (claims frequency) and the size of claims (claims severity) from historical claims data in the past are used to determine pure premiums in the future. The pure premium is generally obtained from the aggregate expected loss value, denoted by $E(S)$ [14].

$$\boldsymbol{E(S) = Claims\ frequency \times Claims\ severity} \quad (5)$$

Meanwhile, in earthquake insurance, the pure risk premium (PRP) of a property can be calculated based on the value of the probability of an earthquake occurring and the building damage ratio, as well as the building insurance value, which is shown through the following equation:

$$\boldsymbol{PRP_k = EADR_k \times INSV} \quad (6)$$

Where $EADR_k$ represents the expected annual damage ratio of building type k, and INSV represents the insured value of the building.

Results And Discussions

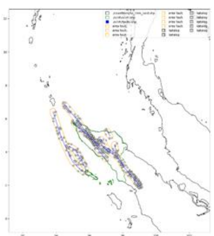
This type of research is quantitative research using two pieces of data: earthquake occurrence data obtained from the ISC Bulletin website and building damage data obtained from BNPB in Aceh Province and North Sumatra Province. These two data are analyzed separately, and the results obtained will be used to calculate the estimated value of pure earthquake insurance premiums. In this research, earthquake data were analyzed using Probabilistic Seismic Hazard Analysis (PSHA) with computational assistance consisting of several software such as QGIS, Jupyter Notebook, and OpenQuake, while building damage data was analyzed using damage ratio values.

Published by: Lembaga Penelitian dan Pengabdian Masyarakat (LPPM)
Institut Teknologi Sumatera, Lampung Selatan, Indonesia

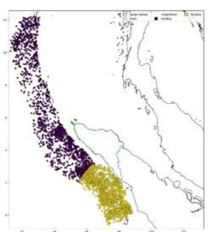
Earthquake Event

The earthquake events used in this research are independent earthquakes, namely only the main earthquake, and do not include foreshocks or aftershocks. Earthquake catalog data for the research location in Banda Aceh City consists of 30,465 earthquake events. Meanwhile, the earthquake catalog data for the research location in Sibolga City consists of 18,277 earthquake events.

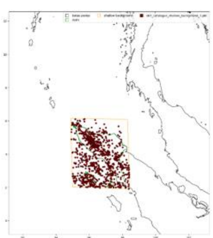
Catalog data is separated based on earthquake sources. This is done to group each earthquake event data based on the source of the earthquake. The earthquake sources in this research are divided into two combined faults, four individual faults, two megathrusts, one shallow background, and one deep background. Visualization of catalog data for each earthquake source in Banda Aceh can be seen in **Figure 1**.



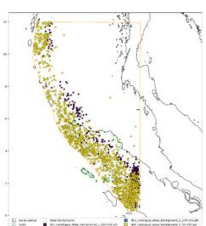
a. Patahan



b. Megathrust



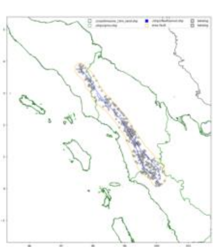
c. Shallow Background



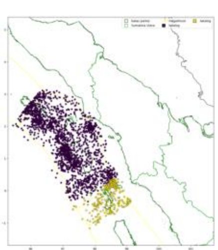
d. Deep Background

Figure 1. Distribution of Earthquake Source Catalog Data for Banda Aceh City

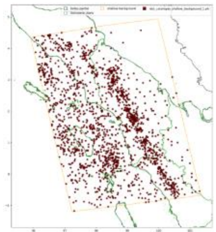
Meanwhile, visualization of catalog data for each earthquake source in Sibolga (**Figure 2).**



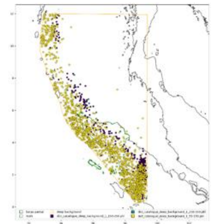
c. Patahan



d. Megathrust



c. Shallow Background



d. Deep Background

Figure 2 Distribution of Earthquake Source Catalog Data for Sibolga City

The number of earthquake events in the earthquake catalog data for Banda Aceh City and Sibolga City has significant differences. This difference shows that the two cities have different risks of exposure to earthquake disasters. Based on the earthquake catalog data above, Banda Aceh City has more earthquake events than Sibolga City. This means the City of Banda Aceh is more vulnerable to earthquake disasters than the City of Sibolga. On the other hand, the number of earthquake incidents in Sibolga City is less than in Banda Aceh City. This means that Sibolga City has a lower risk level for earthquake disasters than Banda Aceh City.

Probability of an Earthquake Event

The probability of an earthquake occurring is obtained based on analysis of earthquake catalog data using the Probabilistic Seismic Hazard Analysis (PSHA) method. The earthquake catalog data in **Table 3** and **Table 4** were processed using QGIS software, Jupyter Notebook, and OpenQuake (**Table 5**).

Table 3. Probability of an Earthquake Event Banda Aceh and Sibolga City

Banda Aceh		Sibolga	
MMI	SH_I	MMI	SH_I
II-III	-	II-III	-
IV	-	IV	$3{,}22 \times 10^{-1}$
V	-	V	$1{,}31 \times 10^{-1}$
VI	$1{,}19 \times 10^{-1}$	VI	$2{,}28 \times 10^{-2}$
VII	$3{,}23 \times 10^{-2}$	VII	$4{,}14 \times 10^{-3}$
VIII	$5{,}60 \times 10^{-3}$	VIII	$5{,}01 \times 10^{-4}$
IX	$2{,}96 \times 10^{-4}$	IX	$1{,}89 \times 10^{-5}$
X+	$2{,}29 \times 10^{-6}$	X+	$1{,}69 \times 10^{-7}$

Based on the analysis results shown in the two tables above, it can be seen that the probability of an earthquake occurring in Banda Aceh City and Sibolga City has different results. However, both results show the same pattern, namely the relationship between the earthquake's intensity or the MMI intensity scale and the probability of an earthquake or SH_I being inversely proportional. This relationship shows that the larger the MMI intensity scale value, the smaller the SH_Ivalue. On the other hand, if the MMI intensity scale value gets smaller, the SH_Ivalue will get bigger. This indicates that earthquake events with a high-intensity scale (usually more than $M_w = 7{,}00$) will occur less frequently.

Building Damage

In this study, the level of building damage was classified into three categories: light, moderate, and heavy. Likewise, the building groups in this study are divided into three categories by SE OJK Number 6/SEOJK.05/2017, namely:

a. Houses included in the residential building type (DW: Steel, Wood, RC).
b. Educational, health, and worship facilities are included in the commercial and industrial building types with construction classes up to nine floors (Com: Steel, Wood, RC ≤ 9).
c. Offices are included in the commercial and industrial building type with a construction class of more than nine floors (Com: Steel, Wood, RC > 9).

Based on the calculation results, the Damage Probability Matrix is obtained as in **Table 4 - Table 8**.

Table 4. Damage Probability Matrix (DPM) Dwelling House in Banda Aceh Cities

Damage State (DS)	Central Damage Ratio (CDR), %	Banda Aceh						
		Intensity (MMI)						
		III	V	VI	VII	VIII	IX	X
Light	5	0,00	0,88	0,02	0,02	0,45	0,46	0,54
Moderate	30	0,00	0,00	0,00	0,00	0,14	0,22	0,00
Heavy	70	1,00	0,12	0,98	0,98	0,41	0,32	0,46

Table 5. Damage Probability Matrix (DPM) Dwelling House in Sibolga Cities

Damage State (DS)	Central Damage Ratio (CDR), %	Sibolga				
		Intensity (MMI)				
		III	V	VI	VII	VIII
Light	5	0,00	0,88	0,02	0,02	0,45
Moderate	30	0,00	0,00	0,00	0,00	0,14
Heavy	70	1,00	0,12	0,98	0,98	0,41

Table 6. *Damage Probability Matrix* (DPM) Commercial and Industrial ≤ 9 Floors in Banda Aceh and Sibolga Cities

Damage State (DS)	Central Damage Ratio (CDR), %	Intensity (MMI)					
		Banda Aceh			Sibolga		
		V	VIII	IX	VII	VIII	IX
Light	5	0,59	0,69	0,44	1,00	0,00	0,22
Moderate	30	0,00	0,19	0,31	0,00	0,00	0,44
Heavy	70	0,41	0,12	0,25	0,00	1,00	0,33

Table 7. *Damage Probability Matrix* (DPM) Commercial and Industrial ≤ 9 Floors in Sibolga Cities

Damage State (DS)	Central Damage Ratio (CDR), %	Intensity (MMI)					
		Banda Aceh			Sibolga		
		V	VIII	IX	VII	VIII	IX
Light	5	0,59	0,69	0,44	1,00	0,00	0,22
Moderate	30	0,00	0,19	0,31	0,00	0,00	0,44
Heavy	70	0,41	0,12	0,25	0,00	1,00	0,33

Table 8. *Damage Probability Matrix* (DPM) Commercial and Industrial > 9 Floors in Banda Aceh dan Sibolga Cities

Damage State (DS)	Central Damage Ratio (CDR), %	Intensity (MMI)						
		Banda Aceh				Sibolga		
		V	VI	VIII	IX	VII	VIII	IX
Light	5	0,47	1,00	0,48	0,06	0,98	0,79	0,35
Moderate	30	0,00	0,00	0,40	0,29	0,00	0,06	0,16
Heavy	70	0,53	0,00	0,12	0,65	0,02	0,15	0,49
Mean Damage Ratio (MDR), %		39,50	5,00	23,06	54,48	6,43	16,76	43,26

In the type of residential buildings in Banda Aceh shown in **Table 9**, the probability of heavy damage status at intensity III is greater than that of light or moderate damage at the same intensity. Likewise, the likelihood of damage status at each intensity can be determined for other intensities according to the damage frequency. Meanwhile, in Sibolga, the lowest probability of light damage is at intensity X. The lowest likelihood of moderate damage is at intensities VII, IX, and X. The lowest likelihood of heavy damage is at intensity IX. The highest likelihood of mild damage is at intensity IX. The highest probability of moderate damage is at intensity V. The highest probability of severe damage is at intensity X. The same applies to commercial and industrial building types with less than nine and more than nine floors (Table 10).

Table 9. *Mean Damage Ratio (MDR) Residential Buildings in Banda Aceh and Sibolga Cities*

Damage State (DS)	Central Damage Ratio (CDR), %	Intensity (MMI)					
		Banda Aceh			Sibolga		
		V	VIII	IX	VII	VIII	IX
Light	5	0,59	0,69	0,44	1,00	0,00	0,22
Moderate	30	0,00	0,19	0,31	0,00	0,00	0,44
Heavy	70	0,41	0,12	0,25	0,00	1,00	0,33
Mean Damage Ratio (MDR), %		31,76	17,59	29,11	5,00	70,00	39,44

Published by: Lembaga Penelitian dan Pengabdian Masyarakat (LPPM)
Institut Teknologi Sumatera, Lampung Selatan, Indonesia

Table 10. *Mean Damage Ratio (MDR) Commercial and Industrial Building Types ≤ 9 Floors in Banda Aceh and Sibolga Cities*

Damage State (DS)	Central Damage Ratio (CDR), %	Intensity (MMI)						
		Banda Aceh				Sibolga		
		V	VI	VIII	IX	VII	VIII	IX
Light	5	0,47	1,00	0,48	0,06	0,98	0,79	0,35
Moderate	30	0,00	0,00	0,40	0,29	0,00	0,06	0,16
Heavy	70	0,53	0,00	0,12	0,65	0,02	0,15	0,49
Mean Damage Ratio (MDR), %		39,50	5,00	23,06	54,48	6,43	16,76	43,26

Table 11. *Mean Damage Ratio (MDR) Commercial and Industrial Building Types > 9 Floors in Banda Aceh and Sibolga Cities*

Damage State (DS)	Central Damage Ratio (CDR), %	Intensity (MMI)					
		Banda Aceh			Sibolga		
		V	VIII	IX	VII	VIII	IX
Light	5	0,59	0,69	0,44	1,00	0,00	0,22
Moderate	30	0,00	0,19	0,31	0,00	0,00	0,44
Heavy	70	0,41	0,12	0,25	0,00	1,00	0,33
Mean Damage Ratio (MDR), %		31,76	17,59	29,11	5,00	70,00	39,44

In the type of residential building shown in **Table 11**, the probability of heavy damage status at intensities III, VI, and VII is greater than the probability of light or moderate damage status so that the average value of the building damage ratio is significant, whereas at intensities V, VIII, IX, and this also applies to commercial and industrial building types with less than nine and more than nine floors.

Expected Annual Damage Ratio

In this research, the expected annual damage ratio (EADR) value describes the percentage of earthquake insurance premium rates from the replacement cost of property units [6], commonly called the premium rate. The EADR value can be calculated using the formula in Equation (4). Based on the results of these calculations, the following results were obtained:

Table 12. Expected Annual Damage Ratio (EADR) Types of Residential Buildings in the Cities of Banda Aceh and Sibolga

Building Type	EADR (%)	
	Banda Aceh	Sibolga
Dwelling House	10,64	3,56
Commercial and Industrial ≤ 9 Floors	0,74	0,035
Commercial and Industrial > 9 Floors	0,11	0,056

From **Table 12**, in the city of Banda Aceh, it can be seen that the premium rate for residential building types is 14.37 times greater than the premium rate for commercial and industrial building types with less than nine floors and 96.72 times greater than the excellent rate for commercial and industrial building types with more than nine floors. Meanwhile, in Sibolga, the highest premium rate was obtained for house buildings. Meanwhile, commercial buildings with ≤9 floors have the lowest premium rates.

Earthquake Insurance Estimated Premium

The building insurance value used in this research refers to the building component cost list (DBKB). DBKB is used because of limited information regarding the current insurance value of buildings and is considered to represent the actual price of the building. The DBKB refers to the Regulation of the Regent of North Aceh, Aceh Province Number 51 of 2019, for the research location in Banda Aceh City. Meanwhile, for the research location in Sibolga City, the DBKB refers to the Regulation of the Mayor of Tebing Tinggi, North Sumatra Province Number 13 of 2021. In general, the premium amount is calculated based on the size of the claim (claims severity) and the number of claims (claims frequency) from historical claims data in the past. However, in Indonesia itself, claim data for earthquake insurance is rarely found, so in this study, the premium amount is calculated based on the value of the probability of an earthquake occurring and the building damage ratio, as well as the building insurance value, which is represented by the value of the building component cost list (DBKB). Thus, the estimated pure risk premium (PRP) value can be calculated using the formula in Equation (6) (**Table 13**).

Table 13. Building Insurance Value for Residential Building Types in the Cities of Banda Aceh and Sibolga Cities

Buliding Type	Type of Building Use	Number of Floors	Building Area (m²)	INSV (Rp/m²)		PRP_k (Rp/m²)	
				Banda Aceh	Sibolga	Banda Aceh	Sibolga
Dwelling House	Housing Area	1	1 - 69	380.000	383.000	40.423 - 2.789.187	13.635 - 940.801
			70 - 99	491.000	494.000	3.656.100 - 5.170.770	1.231.048 - 1.741.054
		2 - 4	1 -69	380.000	383.000	40.423 - 2.789.187	27.270 - 3.763.206
			70 - 99	494.000	505.000	3.678.500 - 5.202.450	2.516.920 - 7.119.288
Commercial and Industrial ≤ 9 Floors	Offices, Pharmacies, Shops, Markets, Shophouses, Restaurants, Hotels, Guesthouses and Government Buildings	1	1 - 69	380.000	383.000	2.818 - 194.442	134 - 9.249
			70 - 99	491.000	494.000	254.940 - 360.558	12.103 - 17.117
		2 - 4	1 - 69	380.000	383.000	2.818 - 194.442	268 - 36.998
			70 - 99	494.000	505.000	256.480 - 362.736	24.745 - 69.993
	Hospital	1	1 - 69	456.000	460.000	3.382 - 233.358	161 - 11.109
			70 - 99	589.000	593.000	305.760 - 432.432	14.528 - 20.547
		2 - 4	1 - 69	456.000	593.000	3.382- 233.358	322 - 44.436
			70 - 99	593.000	606.000	307.860 - 435.402	29.694 - 83.992
Commercial and Industrial > 9 Floors	Workshop, Warehouse and Farm	8 - 10	10 - 13	286.000	400.000	3.060 - 3.978	17.920 - 29.120
		>10	10 - 13	350.000	474.000	29.198 - 37.958	29.198 - 37.958
	Factory	8 -10	10 -13	372.000	520.000	23.296 - 37.856	23.296 - 37.856
		>10	10 - 13	455.000	616.000	37.946 - 49.329	37.946 - 49.329

Based on the results of the analysis above, it can be seen that the estimated value of pure earthquake insurance premiums obtained for residential, commercial, and industrial building types with less than nine floors in Banda Aceh City is more excellent than in Sibolga City. In the residential building type, the estimated value of the pure premium obtained for Banda Aceh City is 2.96 times greater than for Sibolga City, with a price range starting from IDR 40,423 to more than IDR 72,255,700 for Banda Aceh City and IDR 13,635 up to more than IDR 52,552,720 for Sibolga City. Likewise, the estimated pure premium value for commercial and industrial building types with less than nine floors in Banda Aceh City is 21.03 times greater than in Sibolga City, with a price range starting from IDR 2,818 to more than IDR 4,988,500 for Banda City. Aceh and IDR 134 to more than IDR 613,340 for Sibolga City. Meanwhile, the estimated value of pure earthquake insurance premiums for commercial and industrial building types with more than nine floors in Banda Aceh City is 6.42 times smaller than in Sibolga City, with a price range starting from IDR 3,000 to more than IDR 30,636 for Banda Aceh City and IDR 19,253 to more than IDR 275,555 for Sibolga City.

The difference in the estimated pure premium value obtained in this study could be caused by several factors, such as the uneven proportion of building types in the research area because residential building types more dominate it compared to other building types; it could also be caused by incomplete building damage data used. in the analysis of this research, or as a result of other factors not discussed in this research.

Conclusions

Based on the results of data analysis of earthquake events using the Probabilistic Seismic Hazard Analysis (PSHA) method in Banda Aceh City and Sibolga City, it was found that the relationship between the MMI intensity scale and the probability of an earthquake occurring is inversely proportional, namely the greater the MMI intensity scale value, the SH_I value will be. Getting smaller and vice versa. Meanwhile, the analysis of building damage data in Banda Aceh City and Sibolga City obtained an average value of building damage ratio in the range of 5% to 70% for all building types. From this ratio value, a relationship is obtained that the more significant the proportion of heavy damage status, the greater the average value of the building damage ratio, and vice versa. For the calculation of the estimated pure premium value for earthquake insurance in Banda Aceh City and Sibolga City, the results showed that the estimated pure premium value for residential commercial and industrial building types with less than nine floors in Banda Aceh City has a more excellent value of around 2. 96 and 21.03 times compared to Sibolga City. Meanwhile, the estimated pure premium value for commercial and industrial building types with more than nine floors in Banda Aceh City is more minor, around 6.42 times, compared to Sibolga City.

References

[1] Badan Nasional Penanggulangan Bencana (BNPB). (2021). *Indeks Risiko Bencana Indonesia (IRBI)*. Jakarta: Badan Nasional Penanggulangan Bencana.

Published by: Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) Institut Teknologi Sumatera, Lampung Selatan, Indonesia

[2] Pusat Studi Gempa Nasional (PuSGeN). (2017). *Peta Sumber dan Bahaya Gempa Indonesia Tahun 2017*. Bandung: Pusat Litbang Perumahan dan Permukiman.

[3] Badan Nasional Penanggulangan Bencana (BNPB). (2023). *Risiko Bencana Indonesia (RBI)*. Jakarta: Pusat Data, Informasi, dan Komunikasi Kebencanaan BNPB.

[4] Badan Nasional Penanggulangan Bencana (BNPB). (2016). *Risiko Bencana Indonesia (RBI)*. Jakarta: Badan Nasional Penanggulangan Bencana.

[5] Badan Nasional Penanggulangan Bencana (BNPB). (2015). *Kajian Risiko Bencana Aceh 2016-2020*. Jakarta: Badan Nasional Penanggulangan Bencana.

[6] Deniz, A. (2006). Estimation of Earthquake Insurance Premium Rates Based Stochastic Methods. [M.S. - Master of Science]. Middle East Technical University.

[7] Montoya, A. L. (2002). Urban Disaster Management : A Case Study of Earthquake Risk Assessment in Cartago, Costa Rica. *ITC Publication Series No. 96*.

[8] Gupta, I. D. (2002). The State of the Art in Seismic Hazard Analysis. *ISET Journal of Earthquake Technology,* Vol. 39(4), 311-346.

[9] Cornell, C. A. (1968). Engineering Seismic Risk Analysis. *Bulletin of the Seismological Society of America,* Vol. 58(5), 1583-1606.

[10] Baker, J. W. (2015). *Introduction to Probabilistic Seismic Hazard Analysis*. Cambridge, England: Cambridge University Press.

[11] Gürpınar, A., Abalı, M., Yücemen, M. S., & Ye ilçay, Y., (1978). Feasibility of Obligatory Earthquake Insurance in Turkey, Earthquake Engineering Research Center, Civil Engineering Department, Middle East Technical University, Report No. 78-05, Ankara, (in Turkish).

[12] Zobin, V. M., Ventura-Ramírez, J. F., Gutiérrez-Andrade, C. L., Cruz, L. H., & Santibáñez-Ibáñez, S. (2006). The Mw 7.4 Colima, Mexico, Earthquake of 21 January 2003: The Observed Damage Matrix in Colima City and its Comparison with the Damage Probability Matrix. *Natural Hazards,* Vol. 38, 391-410.

[13] Otoritas Jasa Keuangan (OJK). (2019). Buku 4 tentang Perasuransian dalam Seri Literasi Keuangan Tingkat Perguruan Tinggi.

[14] Klugman, S. A., Panjer, H. H., & Willmot, G. E. (2019). *Loss Models : From Data to Decisions*. 5th ed. Hoboken: John Wiley and Sons, Inc.