TERANG

(Teknologi Estimasi keRugian bANgunan akibat Gempa)

Version 1.0
Manual

Prepared by:

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Disclaimer

USERS ARE ADVISED TO REFERENCE THIS SOFTWARE AS FOLLOWS:

Milyardi, R. et al (2025) TERANG: Software for estimating direct physical and operational losses due to earthquakes in school building in the Indonesian region.

Download and Contact

GitHub repository: https://github.com/RoiMilyardi/TERANGv1.0

Support email for questions: *terang.software@gmail.com*

1. Installation

The step-by-step installation procedure of the software, in Windows, is discussed in this section. Note that TERANG v1.0 executable is only made available for Windows machines, however, the software can run directly on a Mac machine using the Matlab source code. Figure 1.1 shows all the files/folder that are downloaded by the user through theTERANG GitHub repository. These are as follows:

- TERANG_Installer.exe this is the main installation file.
- TERANG Manual.pdf this is TERANG's manual and installation guide.
- License.txt is license information file.
- Readme.txt is license information file.

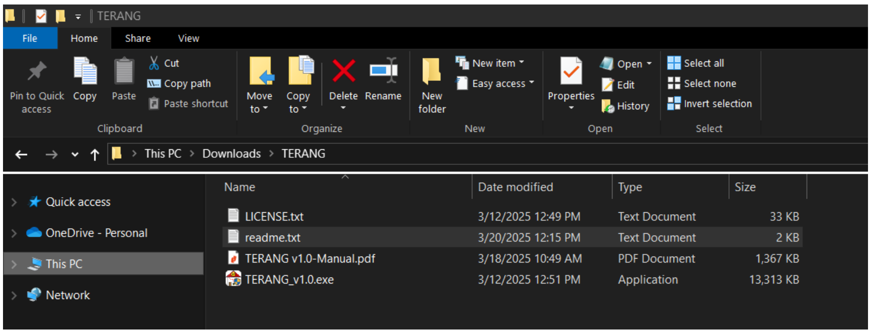
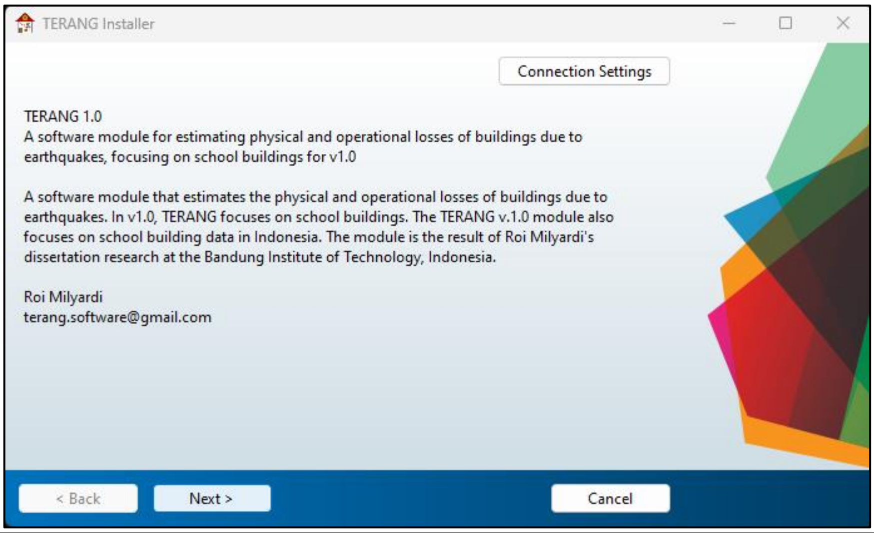
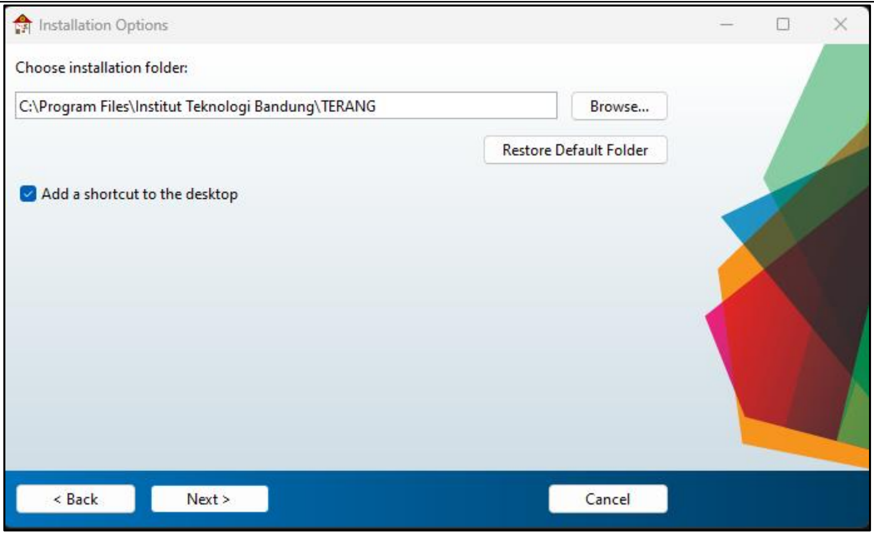


Fig. 1.1 Downloaded software files and folders

The software can be installed by running the EaRL_Installer.exe executable file. As demonstrated in Fig. 1.2, the installation process is like any software. The user is prompted to different windows to approve the installation process and set the installation directory. By default, the installation directory is "C:\Program Files\Institut Teknologi Bandung\TERANG". Note that if MATLAB runtime was not already installed on the local PC, the user will be prompted to download the latest runtime environment (about 700Mb). An internet connection is required in this case. Once installed, the executable file EaRL.exe, as well as other files, can be found in the default installation directory under "…..\Institut Teknologi Bandung\TERANG\application\TERANG.exe" as shown in Fig.1.3.




Installation Options
Choose installation folder:
C:\Program Files\Institut Teknologi Bandung\TERANG
Browse...
Restore Default Folder
Add a shortcut to the desktop
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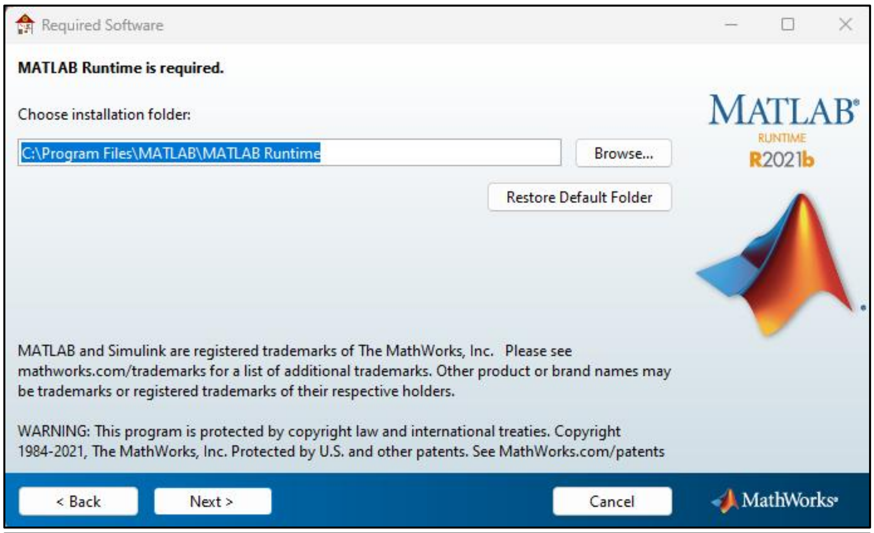
Cancel


Required Software
MATLAB Runtime is required.
Choose installation folder:
C:\Program Files\MATLAB\MATLAB Runtime
Browse...
Restore Default Folder
MATLAB
RUNTIME
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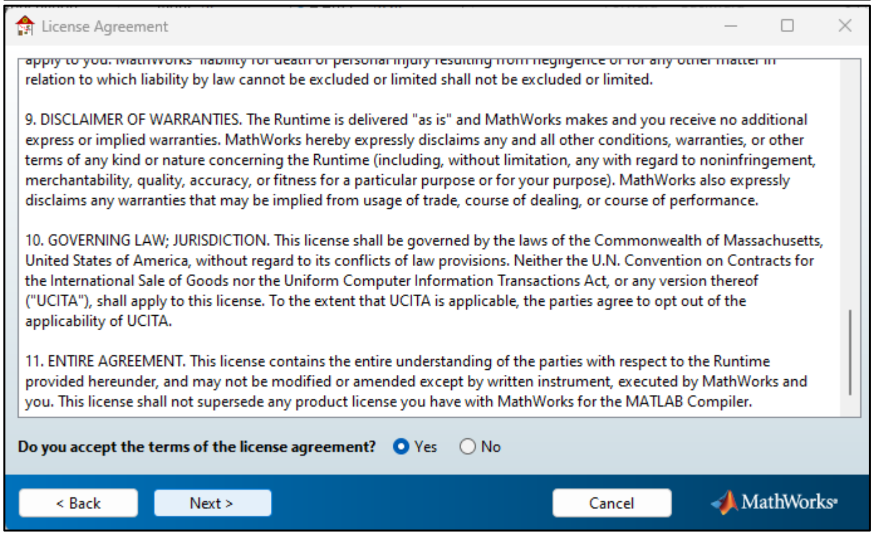
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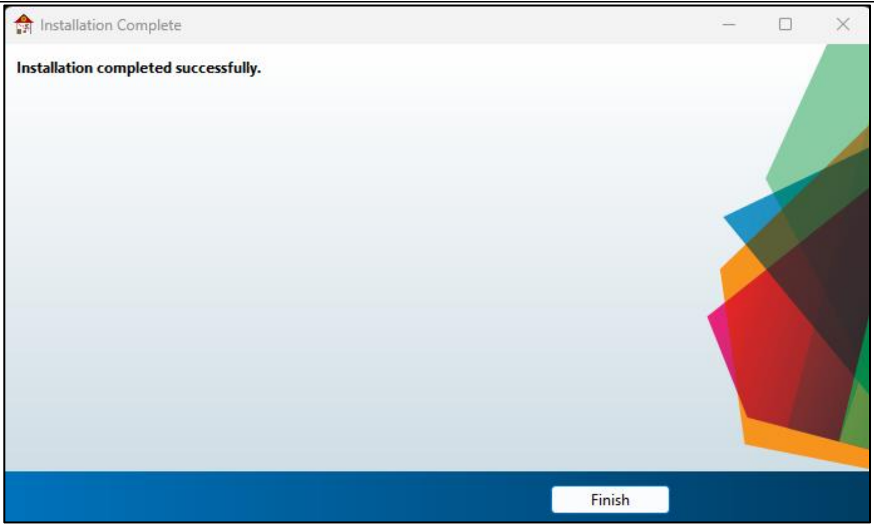


Fig. 1.2 Installation steps

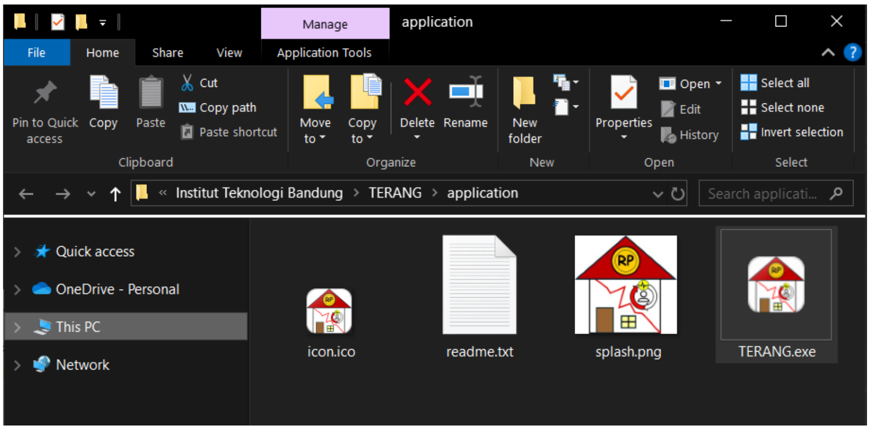


Fig. 1.3 Installed files and folders in the default installation directory

2. Introduction

The HAZUS model developed by Federal Emergency Management Agency (FEMA), USA provides detailed pre-disaster earthquake loss estimation in the form of direct physical and operational losses supported by a complete building database at each regional level (FEMA-NIBS, 2020). The advantage of the HAZUS model is that it provides facilities for the public, not limited to engineers, to perform a series of complex loss estimation procedures through the simplification of cost and structure parameters based on building type supported by a simple software interface (FEMA, 2019). However, the HAZUS software interface is limited to the USA. Pre-disaster estimation models such as HAZUS are needed for disaster-prone countries such as Indonesia(Pribadi et al., 2023). Indonesia needs pre-disaster loss estimation data to prepare disaster-related financial planning. The challenge is that Indonesia does not yet have such a model nor a complete building database like in the USA. The adoption process is a strategic step in accelerating the fulfillment of estimation data needs. However, the constraints of different building characteristics, construction practices, and database availability require adjustments.

To address the above challenges, an open-source computational platform/software called 'TERANG' was developed, which is described in this article. TERANG is the Indonesian acronym for “Teknologi Estimasi keRugian bANgunan akibat Gempa”, which translates to “Technology for estimating building losses due to earthquakes”. TERANG software is a building loss estimation application specific to the Indonesian region with an adaptation of the HAZUS model with modifications to the parameters of reconstruction costs and building costs. In TERANG version 1.0, the building object focuses on school buildings, which according to disaster data are the public buildings most affected by earthquakes (BNPB, 2025). Another difference with the HAZUS interface software, TERANG, focuses the estimation process on 1 building unit. This was made because of the unavailability of school building property data in the national school database in Indonesia (Ministry of Education and Culture of Indonesia, 2025). So that the TERANG software functions as a tool to compile a database of school building properties in Indonesia with a bottom-up system through TERANG users from the school. This tends to be effective because users know their school buildings. In addition, using TERANG software, it serves as education and dissemination of earthquake disaster risk through loss estimation for users in considering risk mitigation with strategic steps of risk transfer (insurance) or investment in strengthening school buildings.

TERANG software is developed with a MATLAB-based user interface. The basic framework of the earthquake loss estimation model used is the HAZUS model. The model consists of 4 stages of analysis, namely hazard analysis, structure analysis, damage analysis, and loss analysis, as detailed in the software process shown in Fig.2.1.

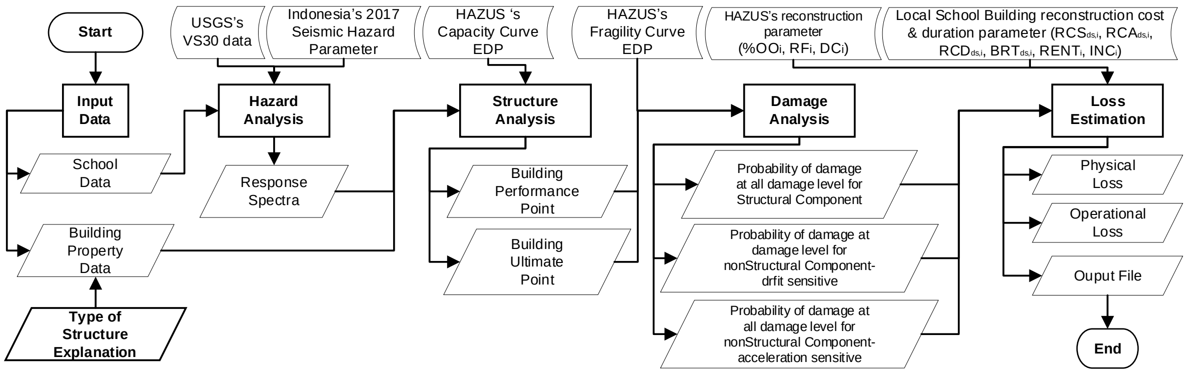


Fig. 2.1. Workflow of the application software (TERANG)

The software TERANG calculates the estimation of earthquake losses in school buildings for the target user school admin but is not limited to civil engineers. Although TERANG is limited to the data set of Indonesia, it provides a significant impact in the form of an illustration of how to adopt the HAZUS model for countries that do not have a school building database like Indonesia for the low barrier user level. In addition, TERANG is also useful in providing significance in the form of earthquake disaster risk education for school building stakeholders, private and public. The TERANG software has been utilized in research on loss estimation in Indonesia, including loss estimation for school buildings in the city of Bandung (R Milyardi et al., 2023), operational loss estimation for schools with $RT_{ds,i}$ modification due to the Mamuju earthquake in 2021(Roi; Milyardi et al., 2024), and sensitivity analysis of the HAZUS structural EDP against loss estimation in a case study of school buildings in Indonesia(Roi Milyardi et al., 2025).

2.a. TERANG limitation

The TERANG software has several limitations, including that earthquake parameters are still limited to city areas (414 city in Indonesia) that are not yet based on real building location coordinates, BRC_i $RENT_i$ and INC_i data taken based on data in the capital city of Jakarta because the data is dynamic based on the decision of the education minister each year. In the software TERANG version 1.0, the BRC_i value assumption taken is 5,000,000IDR/m^2 building area, the value INC_i assumption taken is 2,356.16IDR/m^2/day, while the value $RENT_i$ used is 909.59IDR/m^2/day. Even with this assumption, the estimated value can still be utilized through the ratio value to the building value. The structural types also limited to 3 structural types according to typical school buildings in Indonesia (Gentile et al., 2019; Roi Milyardi et al., 2023).

3. Methodology and Computation Algorithms

3.a. HAZUS methodology

The HAZUS earthquake loss estimation model developed by FEMA in 1992 to estimate earthquake loss in local, state, and regional level with state-of-the-art decision support software. The Geographic Information System (GIS)-based software was applied to small and large area with wide range of population and infrastructure (building, road, and lifeline infrastructures) database and can be implemented by user with varying expertise (FEMA-NIBS, 2020). For general building stock, HAZUS model has four main stage analysis, be made of hazard analysis, structure analysis, damage analysis, and losses analysis. The earthquake losses calculated based on building performance (spectral displacement) and spectral acceleration, with three main replacement components, consists of structural, non-structural drift sensitive, non-structural acceleration sensitive shown in Fig. 3.1 with simplified building performance based on type of structure and building height. The wide-used level expertise user, HAZUS models are reliable to get more wide area earthquake loss estimation. The damage probability on those components used to calculate replacement losses and operational losses. The opposite opinion, non-simplified building performance method conducted with more obstacle, such as limited building losses assessment that need detailed Engineering Demand Parameter (EDP) for each building. FEMA has officially used HAZUS model as an annual earthquake losses estimation in USA in the last 20years. The following sub-section explains more detail for each main stage analysis.

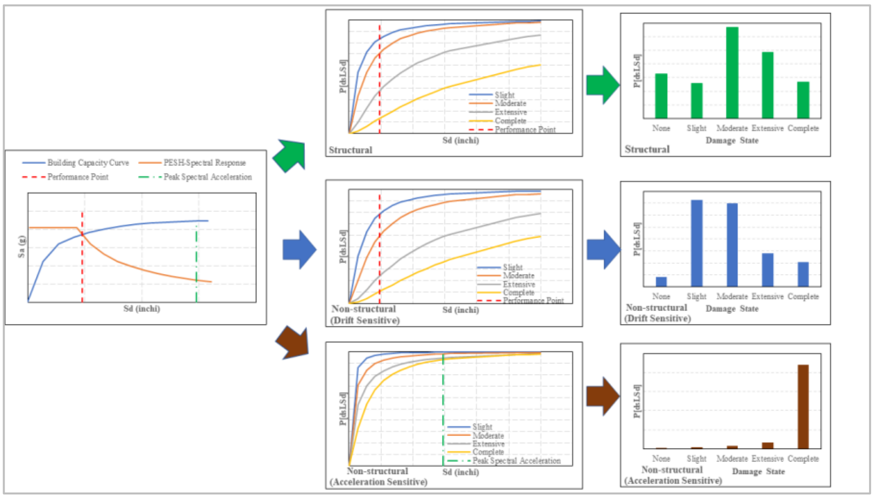
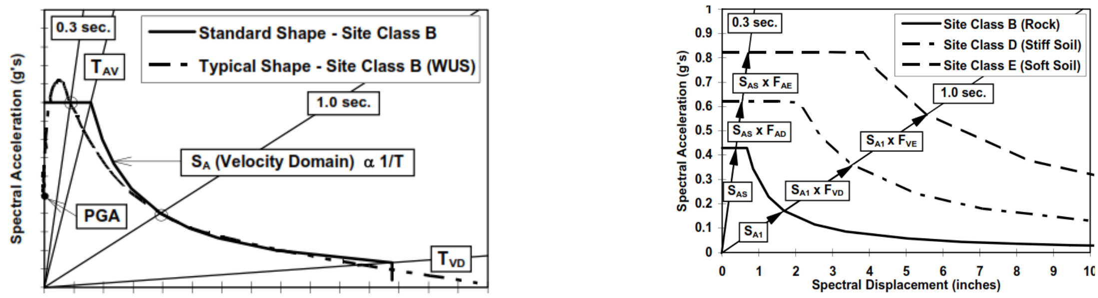


Fig. 3.1 HAZUS earthquake loss conceptual framework

Hazard Analysis

The HAZUS model using demand spectra as a hazard on the location observed shown in Fig. 3.2.b. Demand spectra is constructed based on response spectra parameter (Short period spectral acceleration, 1-second spectral acceleration, and specific site class) shown in Fig. 3.2.a. The response spectra parameters converted into demand spectra parameter (spectral displacement) using Eq.1, where S_D= spectral displacement (inch), S_A=spectral acceleration (g), and T= period for a given value of (seconds).



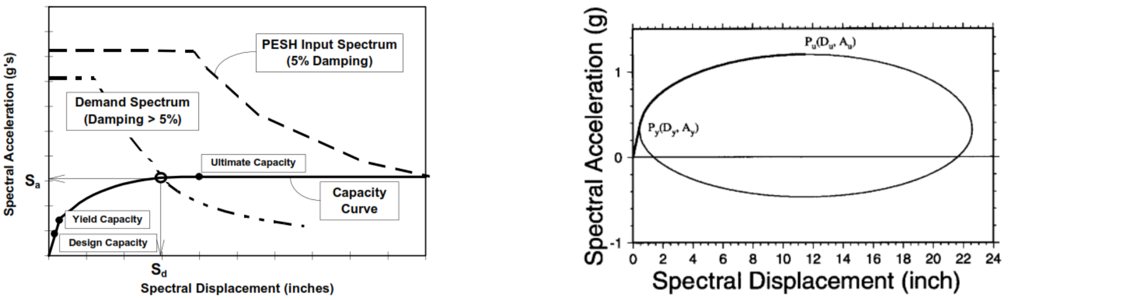
(a) Standardized Response Spectrum (b) Demand spectra construction

Fig. 3.2. HAZUS earthquake loss hazard calculations (FEMA-NIBS, 2020)

$$S_D = 9.8 \times S_A \times T^2 \tag{1}$$

Structure Analysis

In structure analysis, HAZUS uses simplified building capacity performance based on typical building type, level of code, and building height. Total HAZUS has 16 types of structure consist of wood, steel, concrete structure, etc. The building capacity curve superimposed to demand spectra to get building performance shown in Fig. 2.3.a. Building capacity curve constructed using provided yield capacity point, and ultimate capacity can be found in HAZUS manual Table 5-7 until Table 5-10 with different of code level (high code, moderate code, low code, and pre-code) (FEMA-NIBS, 2020). Capacity curve constructed by connect two provided point as transits from elastic to nonlinear plastic states with ellipse form approach shown in Fig. 2.3.b and Eq. 2 to Eq.3, where ellipse parameter (A,B,C) solve with known parameter A_y, D_y, A_u, D_u (Cao & Petersen, 2006).



(a) Building capacity curve (FEMA-NIBS, 2020) (b) Ellipse approach to c yield point to ultimate point(Cao & Petersen, 2006)

Fig. 2.3. HAZUS earthquake loss hazard calculation

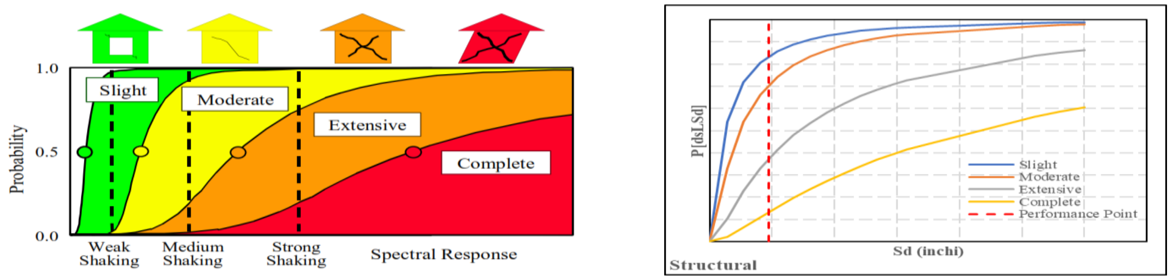
$$\left(\frac{SD - D_u}{C}\right)^2 + \left(\frac{SA - A_x}{B}\right)^2 = 1 \tag{2}$$

$$\frac{dSA}{dSD} = -\left(\frac{SD - D_u}{SA - A_x}\right)\left(\frac{B^2}{C^2}\right) \tag{3}$$

Damage Analysis

Building Fragility Curves are conducted in damage analysis. Fragility curves are the lognormal probability functions for the structural and non-structural damage states (slight, moderate, extensive, and complete) to be reached or exceeded when the peak-responses displacement (SD) is given (Cao &

Petersen, 2006). Building Fragility Curves form shown in Fig. 2.4. Each fragility curve is characterized by median ($\bar{S}_{d,ds}$) and lognormal standard deviation (β_{ds}) show in Eq. 5 (FEMA-NIBS, 2020).



(a) Damage state in fragility curve (FEMA-NIBS, 2020) (b) Building capacity curve form

Fig. 2.4. Building Fragility Curve Form

$$P\left[ds \,||\, S_d\right] = \Phi\left[\frac{1}{\beta_{ds}} \times ln\left(\frac{S_d}{\bar{S}_{d,ds}}\right)\right] \tag{4}$$

$$P\left[ds \le ds(i) \,||\, S_d\right] = \frac{1}{2}\left(1 + erf\left(\frac{ln\left(S_d / \bar{S}_{d,Sds}\right)}{\sqrt{2}\beta_{ds}}\right)\right), i = 1,2,3,4 \tag{5}$$

From Eq. 4, the equation can be rewritten in a more compact form by using the error function erf shown in Eq. 5, where, *i*, refer for each damage states(Cao & Petersen, 2006). The value $\bar{S}_{d,ds}$ and β_{ds} can be found in HAZUS manual Table 5-12 until Table 5-21 for structural and non-structural component with each damage states (FEMA-NIBS, 2020).

Losses Analysis

HAZUS calculates Earthquake direct economic losses component, contain building repair costs, building content losses, building inventory losses, relocation expenses, income loss, rental income losses, and wage losses. All of the loses component calculated based on previous stage analysis. For education facility, earthquake economic losses limited on some component due to different activity, especially on business activity. Earthquake economic losses that relevant in education facility calculated by formula shown in Eq.6 to Eq. 10. Structure repair cost calculated in Eq. 6, where BRC_i is Building replacement cost, $PMBTSTR_{ds,i}$ is probability of structure being in structural damage state, $RCS_{ds,i}$ structural repair cost ratio in damage state that provided in HAZUS manual Table 11-2 (FEMA-NIBS, 2020). In Eq. 7 and 8, Non-structural economic losses calculated into non-structural drift sensitive component and acceleration sensitive component, where $PONSA_{ds,i}$ = probability of building being in non-structural acceleration sensitive damage state, $RCA_{ds,i}$ is non-structural acceleration sensitive repair cost ratio in damage state that provide in HAZUS manual Table 11-3 (FEMA-NIBS, 2020), $PONSD_{ds,i}$ is probability of building being in non-structural drift sensitive damage state, $RCD_{ds,i}$ is non-structural drift sensitive repair cost ratio in damage state that provide in HAZUS manual Table 11-4(FEMA-NIBS, 2020). Relocation expenses conducted as losses that considered when existing building was repaired and calculated base time dependent function shown in Eq. 9, where FA_i is floor area of the building, %OO_i is percent building occupied (95% for building school) (FEMA, 2021), DC_i is disruption cost (1.16 \$/ft^2 for building school) (FEMA, 2021), $RENT_i$ is the rental cost (0.04 \$/ft^2/day for building school) (FEMA, 2021), and RT_{ds} is recovery time state that provide in HAZUS manual Table 11-8(FEMA-NIBS, 2020). Income losses considered losses of income during building recovery time shown in Eq. 10, where INC_i is income per day, and MOD_{ds} is loss of function time modifier for damage state that state provide in HAZUS manual Table 11-8 and Table 11-9 (FEMA-NIBS, 2020).

$$CS_{ds,i} = BRC_i \times \sum_{ds=1}^{4} PMBTSTR_{ds,i} \times RCS_{ds,i} \tag{6}$$

$$CNSA_{ds,i} = BRC_i \times \sum_{ds=1}^{4} PONSA_{ds,i} \times RCA_{ds,i} \tag{7}$$

$$CNSD_{ds,i} = BRC_i \times \sum_{ds=1}^{4} PONSD_{ds,i} \times RCD_{ds,i} \tag{8}$$

$$REL_{ds,i} = FA_i \times \left[(1-\%OO_i) \times \sum_{ds=1}^{4} \left(POSTR_{ds,i} \times DC_i \right) + \%OO_i \times \sum_{ds=1}^{4} \left(POSTR_{ds,i} \times \left(DC_i + RENT_i \times RT_{ds} \right) \right) \right] \tag{9}$$

$$YLOS_i = (1 - RF_i) \times FA_i \times INC_i \times \sum_{ds=1}^{4} POSTR_{ds,i} \times RT_{ds} \times MOD_{ds} \tag{10}$$

3.b. Modification and Adaption of HAZUS parameters in TERANG software

Modifications were made at each stage of the analysis. At the hazard analysis stage, a response spectrum curve was constructed, as shown in Fig.2b, following the procedure of the National Seismic Building Code (SNI 1726: 2019) (Badan Standardisasi Nasional, 2019), with 3 earthquake parameters (Ss, S1, TL) from the 2017 Indonesian National Earthquake Map, automatically obtained based on the seismicity area data selected in Data Input (Ministry of Public Works and Housing of Indonesia, 2021). In obtaining the parameters for the other 7 return periods (where the earthquake map only provides a return period of 1-2500 years), Eq. 11 from the Eurocode is used for their equivalence, where a_g = the value of the sought earthquake acceleration, a_{gR}= the reference value of the earthquake acceleration, T= the value of the sought earthquake recurrence period, T_R= the reference value of the recurrence period, and k = the seismic coefficient taken as 0.4(CEN, 2005).

$$\frac{a_g}{a_{gR}} = \left(\frac{T}{T_R} \right)^k \tag{11}$$

At the structural analysis stage, the capacity curve is constructed based on EDP yield point (D_y, A_y), and ultimate point (D_u, A_u) from the HAZUS model according to the type of structure as shown in Table 3.2. The structure type in TERANG v1.0 is limited to 3 structure types with varying levels of code and structure height according to typical school buildings in Indonesia(Roi Milyardi et al., 2023). Code level determination is adjusted to the development of Indonesian code as show in Table 3.1. In addition, the elliptical equation that has been derived for the transfer of the yield point to the ultimate point is used, shown in Eq.12 to Eq. 15.

$$S_a = \sqrt{B^2 \times \left(1 - \frac{(S_D - D_U)^2}{C^2}\right)} + A_x \tag{12}$$

$$A_x = \frac{(D_Y - D_Y{}^2 + 2D_U D_Y - D_U{}^2) \times A_Y{}^2 - D_Y A_U{}^2}{(2D_Y A_Y - 2D_Y A_U - D_Y{}^2 A_Y + 2D_U D_Y A_Y - A_Y D_U{}^2)} \tag{13}$$

$$B = \sqrt{(A_U - A_x)^2} \tag{14}$$

$$C = \sqrt{\frac{B^2 - (D_y - D_u)^2}{B^2 - (A_y - A_X)^2}} \tag{15}$$

Table 3.1. Indonesia's Building seismic design level classification (Muntafi et al., 2020; Nugroho et al., 2022)

Seismic design level	Year of construction
High-Code	After 2012
Moderate Code	1991-2012
Low Code	1970-1991
Pre Code	Before 1970

Table 3.2. Adoption of HAZUS's EDP Structure Capacity Curve (FEMA-NIBS, 2020).

Level of Code	Type of Structure	Heigh of Structure	Structure ID	Dy (mm)	Ay (g)	Du (mm)	Au (g)
High-Code	S1 (Steel Moment Frame)	Low-Rise (1-3 Stories)	S1LH	15.5194	0.25	372.5418	0.749
		Mid-Rise (4-7 Stories)	S1MH	45.085	0.156	721.36	0.468
		High-Rise (8+ Stories)	S1HH	118.2878	0.098	1419.454	0.293
	C1 (Concrete Moment Frame)	Low-Rise (1-3 Stories)	C1LH	9.9314	0.25	238.4298	0.749
		Mid-Rise (4-7 Stories)	C1MH	29.2608	0.208	468.2744	0.624
		High-Rise (8+ Stories)	C1HH	51.0794	0.098	612.902	0.293
	RM1 (Reinforced Masonry Wall)	Low-Rise (1-3 Stories)	RM1LH	16.2306	0.533	259.8166	1.066
		Mid-Rise (4+Stories)	RM1MH	35.1536	0.444	374.904	0.889
Moderate-Code	S1 (Steel Moment Frame)	Low-Rise (1-3 Stories)	S1LM	7.7724	0.125	139.7	0.375
		Mid-Rise (4-7 Stories)	S1MM	22.5552	0.078	270.5354	0.234
		High-Rise (8+ Stories)	S1HM	59.1566	0.049	532.3078	0.147
	C1 (Concrete Moment Frame)	Low-Rise (1-3 Stories)	C1LM	4.9784	0.125	89.408	0.375
		Mid-Rise (4-7 Stories)	C1MM	14.6304	0.104	175.6156	0.312
		High-Rise (8+ Stories)	C1HM	25.527	0.049	229.8446	0.147
	RM1 (Reinforced Masonry Wall)	Low-Rise (1-3 Stories)	RM1LM	8.128	0.267	97.4344	0.533
		Mid-Rise (4+Stories)	RM1MM	17.5768	0.222	140.589	0.444
Low-Code	S1 (Steel Moment Frame)	Low-Rise (1-3 Stories)	S1LL	3.8862	0.062	58.2168	0.187
		Mid-Rise (4-7 Stories)	S1ML	11.2776	0.039	112.6998	0.117
		High-Rise (8+ Stories)	S1HL	29.5656	0.024	221.7928	0.073

Level of Code	Type of Structure	Heigh of Structure	Structure ID	Dy (mm)	Ay (g)	Du (mm)	Au (g)
	C1 (Concrete Moment Frame)	Low-Rise (1-3 Stories)	C1LL	2.4892	0.062	37.2618	0.187
		Mid-Rise (4-7 Stories)	C1ML	7.3152	0.052	73.1774	0.156
		High-Rise (8+ Stories)	C1HL	12.7762	0.024	95.758	0.073
	RM1 (Reinforced Masonry Wall)	Low-Rise (1-3 Stories)	RM1LL	4.064	0.133	40.5892	0.267
		Mid-Rise (4+Stories)	RM1ML	8.7884	0.111	58.5724	0.222
Pre-Code	S1 (Steel Moment Frame)	Low-Rise (1-3 Stories)	S1LP	3.8862	0.062	58.2168	0.187
		Mid-Rise (4-7 Stories)	S1MP	11.2776	0.039	112.6998	0.117
		High-Rise (8+ Stories)	S1HP	29.5656	0.024	221.7928	0.073
	C1 (Concrete Moment Frame)	Low-Rise (1-3 Stories)	C1LP	2.4892	0.062	37.2618	0.187
		Mid-Rise (4-7 Stories)	C1MP	7.3152	0.052	73.1774	0.156
		High-Rise (8+ Stories)	C1HP	12.7762	0.024	95.758	0.073
	RM1 (Reinforced Masonry Wall)	Low-Rise (1-3 Stories)	RM1LP	4.064	0.133	40.5892	0.267
		Mid-Rise (4+Stories)	RM1MP	8.7884	0.111	58.5724	0.222

At the damage analysis stage, the three fragility curves were created using EDP (beta (β_{ds}) and median ($\bar{S}_{d,ds}$)) for each damage level and curves based on HAZUS model data for structural components, non-structural drift-sensitive, and non-structural acceleration-sensitive components as shown in Table 3.3 until Table 3.5.

Table 3.3. Adoption of HAZUS's EDP Structural Component Fragility Curve (FEMA-NIBS, 2020).

Structure ID	Slight		Moderate		Extensive		Complete	
	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta
S1LH	33.02	0.80	65.79	0.76	164.59	0.69	438.91	0.72
S1MH	54.86	0.65	109.73	0.65	274.32	0.67	731.52	0.74
S1HH	85.60	0.64	171.20	0.64	427.99	0.65	1141.22	0.67
C1LH	22.86	0.81	45.72	0.84	137.16	0.86	365.76	0.80
C1MH	38.10	0.68	76.20	0.67	228.60	0.68	609.60	0.81
C1HH	54.86	0.66	109.73	0.64	329.18	0.67	877.82	0.78
RM1LH	18.29	0.84	36.58	0.86	109.73	0.92	320.04	1.01
RM1MH	30.48	0.71	60.96	0.80	182.88	0.77	533.40	0.75
S1LM	33.02	0.80	56.90	0.76	129.03	0.74	329.18	0.87
S1MM	54.86	0.65	95.00	0.68	214.88	0.69	548.64	0.87
S1HM	85.60	0.64	148.08	0.64	335.53	0.71	855.98	0.83
C1LM	22.86	0.89	39.62	0.90	106.68	0.90	274.32	0.88
C1MM	38.10	0.69	66.04	0.69	177.80	0.69	457.20	0.90
C1HM	54.86	0.66	95.00	0.67	256.03	0.76	658.37	0.91
RM1LM	18.29	0.96	31.75	1.00	85.60	1.05	240.03	0.94
RM1MM	30.48	0.82	52.83	0.82	142.49	0.80	400.05	0.88
S1LL	33.02	0.78	52.58	0.78	111.25	0.78	274.32	0.96
S1ML	54.86	0.68	87.38	0.78	185.42	0.85	457.20	0.98
S1HL	85.60	0.66	136.40	0.70	289.05	0.76	713.23	0.92

Structure ID	Slight		Moderate		Extensive		Complete	
	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta
C1LL	22.86	0.95	36.58	0.91	91.44	0.85	228.60	0.97
C1ML	38.10	0.71	60.96	0.74	152.40	0.86	381.00	0.98
C1HL	54.86	0.70	87.88	0.81	219.46	0.89	548.64	0.97
RM1LL	18.29	1.12	29.21	1.10	73.41	1.10	200.15	0.92
RM1ML	30.48	0.87	48.77	0.84	122.17	0.79	333.25	0.96
S1LP	26.42	0.85	41.91	0.83	88.90	0.79	219.46	0.95
S1MP	43.94	0.71	70.10	0.76	148.34	0.82	365.76	0.97
S1HP	68.58	0.68	109.22	0.71	231.39	0.85	570.48	0.93
C1LP	18.29	0.98	29.21	0.94	73.15	0.90	182.88	0.96
C1MP	30.48	0.73	48.77	0.77	121.92	0.84	304.80	0.98
C1HP	43.94	0.71	70.10	0.80	175.51	0.94	438.91	1.01
RM1LP	14.73	1.20	23.37	1.17	58.67	1.17	160.02	0.94
RM1MP	24.38	0.92	39.12	0.89	97.79	0.88	266.70	0.96

Table 3.4. Adoption of HAZUS's EDP nonstructural drift sensitive Component Fragility Curve (FEMA-NIBS, 2020).

Structure ID	Slight		Moderate		Extensive		Complete	
	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta
S1LH	21.84	0.81	43.94	0.85	137.16	0.77	274.32	0.76
S1MH	54.86	0.72	109.73	0.72	342.90	0.72	685.80	0.80
S1HH	114.05	0.72	228.35	0.71	713.23	0.74	1426.46	0.77
C1LH	18.29	0.85	36.58	0.88	114.30	0.90	228.60	0.89
C1MH	45.72	0.72	91.44	0.73	285.75	0.75	571.50	0.85
C1HH	87.88	0.71	175.51	0.71	548.64	0.78	1097.28	0.89
RM1LH	18.29	0.89	36.58	0.91	114.30	0.97	228.60	1.06
RM1MH	45.72	0.82	91.44	0.86	285.75	0.80	571.50	0.81
S1LM	21.84	0.85	43.94	0.83	137.16	0.79	274.32	0.87
S1MM	54.86	0.72	109.73	0.74	342.90	0.85	685.80	0.95
S1HM	114.05	0.71	228.35	0.73	713.23	0.84	1426.46	0.95
C1LM	18.29	0.92	36.58	0.96	114.30	0.95	228.60	0.89
C1MM	45.72	0.76	91.44	0.76	285.75	0.87	571.50	0.98
C1HM	87.88	0.74	175.51	0.81	548.64	0.95	1097.28	1.03
RM1LM	18.29	1.01	36.58	1.06	114.30	1.11	228.60	1.01
RM1MM	45.72	0.89	91.44	0.85	285.75	0.84	571.50	0.98
S1LL	21.84	0.86	43.94	0.84	137.16	0.88	274.32	1.00
S1ML	54.86	0.75	109.73	0.89	342.90	0.99	685.80	1.05
S1HL	114.05	0.75	228.35	0.87	713.23	0.97	1426.46	1.04
C1LL	18.29	1.00	36.58	0.96	114.30	0.90	228.60	1.02
C1ML	45.72	0.79	91.44	0.88	285.75	0.99	571.50	1.06
C1HL	87.88	0.87	175.51	0.96	548.64	1.02	1097.28	1.07

Structure ID	Slight		Moderate		Extensive		Complete	
	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta
RM1LL	18.29	1.16	36.58	1.12	114.30	1.03	228.60	0.99
RM1ML	45.72	0.89	91.44	0.89	285.75	1.00	571.50	1.05
S1LP	21.84	0.90	43.94	0.87	137.16	0.91	274.32	1.02
S1MP	54.86	0.80	109.73	0.92	342.90	1.00	685.80	1.06
S1HP	114.05	0.79	228.35	0.89	713.23	1.00	1426.46	1.07
C1LP	18.29	1.02	36.58	0.98	114.30	0.93	228.60	1.03
C1MP	45.72	0.82	91.44	0.91	285.75	1.02	571.50	1.06
C1HP	87.88	0.90	175.51	0.99	548.64	1.05	1097.28	1.10
RM1LP	18.29	1.22	36.58	1.14	114.30	1.03	228.60	1.00
RM1MP	45.72	0.93	91.44	0.92	285.75	1.02	571.50	1.07

Table 3.5. Adoption of HAZUS's EDP nonstructural acceleration sensitive Component Fragility Curve (FEMA-NIBS, 2020).

Structure ID	Slight		Moderate		Extensive		Complete	
	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta
S1LH	7.62	0.67	15.24	0.67	30.48	0.67	60.96	0.66
S1MH	7.62	0.67	15.24	0.68	30.48	0.67	60.96	0.67
S1HH	7.62	0.69	15.24	0.67	30.48	0.67	60.96	0.67
C1LH	7.62	0.67	15.24	0.68	30.48	0.67	60.96	0.67
C1MH	7.62	0.67	15.24	0.67	30.48	0.66	60.96	0.66
C1HH	7.62	0.66	15.24	0.66	30.48	0.66	60.96	0.66
RM1LH	7.62	0.71	15.24	0.67	30.48	0.67	60.96	0.63
RM1MH	7.62	0.72	15.24	0.66	30.48	0.65	60.96	0.65
S1LM	6.35	0.67	12.70	0.66	25.40	0.67	50.80	0.67
S1MM	6.35	0.66	12.70	0.67	25.40	0.67	50.80	0.67
S1HM	6.35	0.66	12.70	0.67	25.40	0.67	50.80	0.67
C1LM	6.35	0.67	12.70	0.66	25.40	0.66	50.80	0.66
C1MM	6.35	0.66	12.70	0.66	25.40	0.63	50.80	0.63
C1HM	6.35	0.65	12.70	0.67	25.40	0.67	50.80	0.67
RM1LM	6.35	0.69	12.70	0.67	25.40	0.67	50.80	0.67
RM1MM	6.35	0.67	12.70	0.64	25.40	0.67	50.80	0.67
S1LL	5.08	0.65	10.16	0.68	20.32	0.68	40.64	0.68
S1ML	5.08	0.66	10.16	0.69	20.32	0.69	40.64	0.69
S1HL	5.08	0.67	10.16	0.65	20.32	0.65	40.64	0.65
C1LL	5.08	0.65	10.16	0.68	20.32	0.68	40.64	0.68
C1ML	5.08	0.65	10.16	0.68	20.32	0.68	40.64	0.68
C1HL	5.08	0.67	10.16	0.67	20.32	0.67	40.64	0.67
RM1LL	5.08	0.66	10.16	0.66	20.32	0.64	40.64	0.64
RM1ML	5.08	0.64	10.16	0.66	20.32	0.64	40.64	0.64
S1LP	5.08	0.66	10.16	0.68	20.32	0.68	40.64	0.68

Structure ID	Slight		Moderate		Extensive		Complete	
	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta	Median (mm)	Beta
S1MP	5.08	0.66	10.16	0.69	20.32	0.69	40.64	0.69
S1HP	5.08	0.67	10.16	0.67	20.32	0.67	40.64	0.67
C1LP	5.08	0.66	10.16	0.68	20.32	0.68	40.64	0.68
C1MP	5.08	0.66	10.16	0.68	20.32	0.68	40.64	0.68
C1HP	5.08	0.67	10.16	0.67	20.32	0.67	40.64	0.67
RM1LP	5.08	0.66	10.16	0.67	20.32	0.66	40.64	0.66
RM1MP	5.08	0.64	10.16	0.66	20.32	0.65	40.64	0.65

At the loss analysis stage, Losses are categorized into physical losses, $RCL_{ds,i}$, and operational losses, $OCL_{ds,i}$, shown in Eq.16 and Eq.17. The modification of HAZUS parameters in TERANG software consists of $RCS_{ds,i}$ structural repair cost ratio in damage state (%), $RCA_{ds,i}$ is non-structural acceleration sensitive repair cost ratio in damage state (%), $RCD_{ds,i}$ is non-structural drift sensitive repair cost ratio in damage state (%), RT_{ds} is recovery time parameters (days), and $RENT_i$ is the building rental cost (IDR/m^2/day), and INC_i is building income (IDR/m^2/day) as shown in Table 5. The adjustment of $RENT_i$ and INC_i variables developed based on local data shown in Eq.18 and Eq.19, where HSBGN is the unit price of the building (IDR/m^2), and BOS_n is the incentive value for school buildings (IDR/m^2/day). HSBGN and BOS_n data taken based on data in the capital city of Jakarta (5,000,000IDR/m^2 and 1,720,000 IDR/year) because the data is dynamic based on the decision of the education minister each year. The remaining parameters $\%OO_i$, DC_i, RF_i, MOD_{ds} are parameters adopted from the HAZUS model as shown in Table 3.6.

$$RCL_{ds,i} = CS_{ds,i} + CNSD_{ds,i} + CNSD_{ds,i} \quad (16)$$

$$OCL_{ds,i} = REL_{ds,i} + YLOS_{ds,i} \quad (17)$$

$$RENT_i = \frac{6.64\% \times HSBGN}{365} \quad (18)$$

$$INC_i = \frac{BOS_n}{730} \quad (19)$$

Table 3.6. Modification and Adoption of HAZUS's Loss Parameter

Parameter	Units	Level of Damage				Note
		Slight	Moderate	Extensive	Complete	
$RCS_{ds,i}$	%	3.32	3.32	10.72	40.88	From Local Earthquake Case (On-going Research)
$RCD_{ds,i}$	%	8.06	8.06	8.17	24.77	
$RCA_{ds,i}$	%	11.9	11.9	13.07	27.91	
RT_{ds}	days	768	768	768	768	From Mamuju Case Study Research (Roi Milyardi et al., 2024)
$RENT_i$	IDR/m^2/day	909.59				From Eq. 18, where HSBGN=5,000,000IDR/m^2
INC_i	IDR/m^2/day	2,356.16				From Eq. 19, where BOSn=1,720,000IDR/year

Parameter	Units	Level of Damage				Note
		Slight	Moderate	Extensive	Complete	
$\%OO_i$	%	95				Adoption From HAZUS (FEMA, 2021)
DC_i	IDR/m^2	187,292.12				Adoption From HAZUS (FEMA, 2021)
RF_i	%	60				Adoption From HAZUS (FEMA, 2021)
MOD_{ds}	-	0.1	0.02	0.03	0.03	Adoption From HAZUS (FEMA-NIBS, 2020)

4. TERANG User Guide

In general, the TERANG software display consists of 6 tabs, namely Input Data Tab, Hazard Analysis Tab, Structure Analysis Tab, Damage Analysis Tab, Loss Analysis Tab, Type of Structure Explanation Tab as shown in Fig.4.1. This software provides 2 languages, namely English and Bahasa Indonesia, which can be clicked on the respective language selection buttons.

4a. Input Data & Type of Structure Explanation Tab

The Data Input tab is shown on Fig.4.1. In general, it consists of 3 group panels, namely School Data, Building Property Data, and Explanation of Data Input.

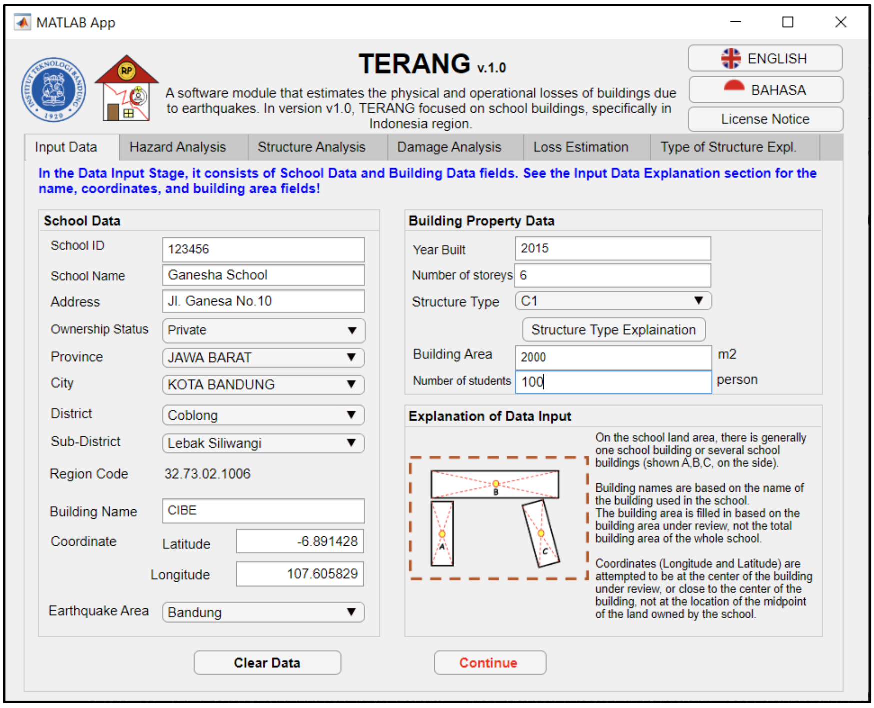


Fig. 4.1. TERANG's Input Data Tab

In the School Data group panel, the following data is inputted:

a. School ID is filled in according to the ID from the Ministry of Education (MoE) data that can be accessed on the Page: https://dapo.kemdikbud.go.id/

b. School Name is also filled in according to the MoE data.

c. The address is filled with the school location

d. Ownership status is filled with Private / Public status

e. Province, selected according to the location of the school province. Territorial data is limited to Indonesia.
f. The city will be automatically filtered according to the previously selected Province, then please select the city according to the location of the school.
g. The district will be automatically filtered according to the previously selected City, then please select the district according to the school location.
h. Sub-District will be automatically filtered according to the previously selected District, then please select the Sub-District according to the school location.
i. The Region code will automatically appear according to the selected sub-district. The Region Code that appears is in accordance with the registration code of the Indonesian Ministry of Home Affairs
j. In filling in the Building Name, it is necessary to see the illustration on the 'Explanation of Data Input' panel. So, the building name is filled in according to the building under review. One school may have more than one building.
k. Coordinates filled in latitude and longitude in decimal format
l. Earthquake area is selected based on the available city or region. If the city/region does not exist, the nearest region can be selected.

The Group panel ‘Building Properties Data’ is entered as follows:

a. Year built in the observed building data. Remember, the year built in 1 school complex may be different from another.
b. The number of floors is filled in the observed building
c. For the structure type, C1, RM1, and S1 can be selected. If you have difficulty understanding the structure type, you can click the ‘Structure Type Explanation’ button which will take you to Fig.4.2. In the ‘Type of Structure Expl.’ tab, you can identify the type of building structure according to the explanation. When finished, click the ‘Back to Input Data’ button.
d. Building area is filled in the total building area of the observed building
e. Number of students is filled in the number of students who occupy the building in the observed building

The ‘**Clear data**’ button is used to reset the data fields.

The ‘**Continue**’ button is used to proceed to hazard analysis.

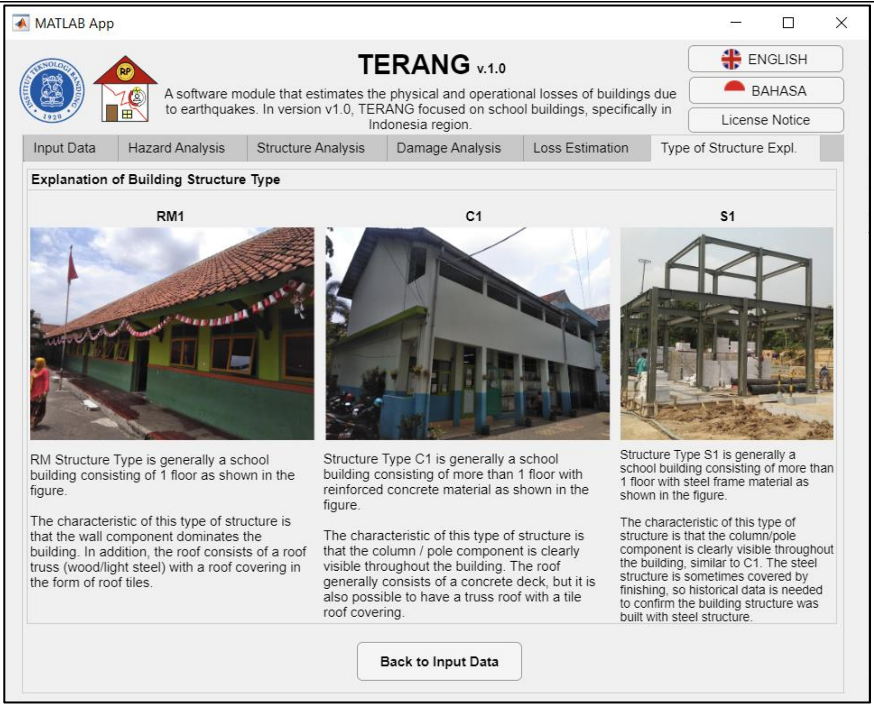


Fig. 4.2. TERANG's Type of Structure Explanation Tab

4b. Hazard Analysis Tab

The Hazard Analysis tab is shown in Fig.4.3.

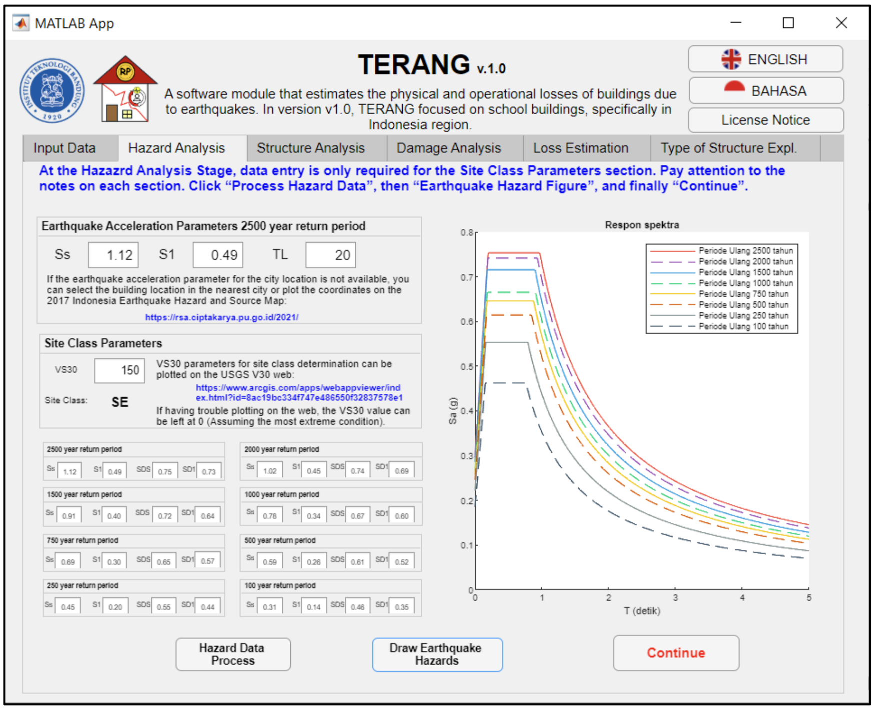


Fig. 4.3. TERANG's Hazard Analysis Tab

In Hazard analysis, in general, only VS30 data input is required. The following are the detailed steps.

a. In the group panel 'Earthquake Acceleration Parameter 2500 year return period' the values of SS, S1, and TL will be automatically filled in according to the earthquake region selected in the

Data Input Tab. If the earthquake region is not found, the user can select the nearest earthquake region, or fill in the SS, S1, and TL parameters according to the building coordinates obtained from the website: https://rsa.ciptakarya.pu.go.id/2021/

b. In the site class parameter, the VS30 parameter can be filled in according to the building coordinates obtained from the website: https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=8ac19bc334f747e486550f32837578e1 . If the user finds it difficult to access the website, the VS30 value can be filled in as 0, with the consequences of the most extreme scenario.

c. In the 8 Group Panel 2500 year return period to 100 year return period, and the hazard graph curve will be automatically filled in when pressing the '**Hazard Data Process**' and '**Draw Earthquake hazards**' buttons

d. After both buttons are pressed, you can click '**Continue**'.

4c. Structure Analysis Tab

The structure analysis is shown in Figure 4.4. No data entry is required at this stage.

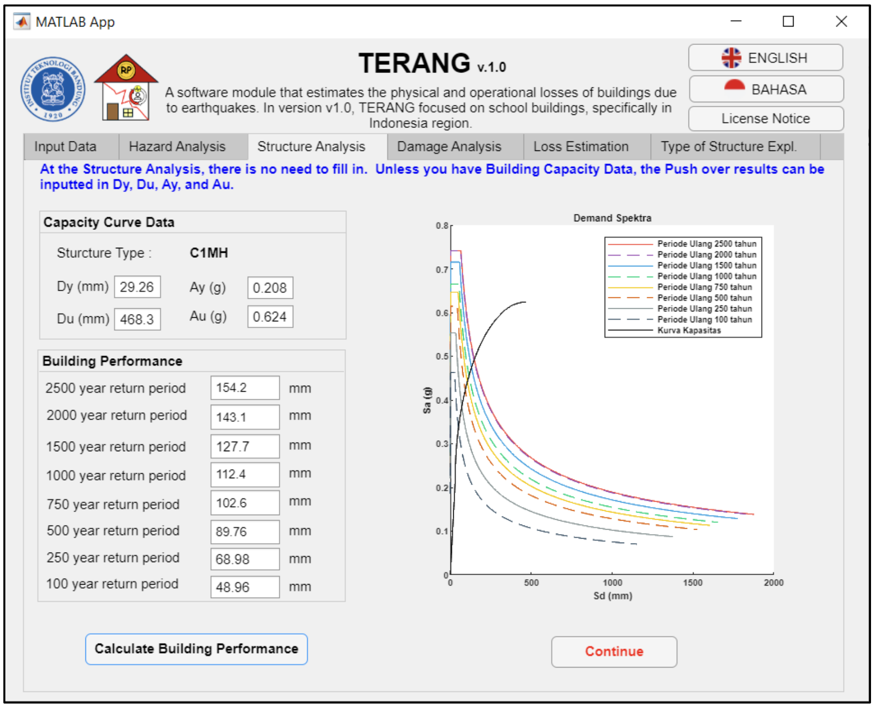


Fig. 4.4. TERANG's Structure Analysis Tab

Here are the detailed steps.

a. In the Capacity Curve Data panel group, the Structure type, Dy, Ay, Du, and Au values will be automatically filled in according to the data input. For the parameters Dy, Ay, Du, and Au can be modified if the user has technical pushover building result data. This is only recommended for advance use who have structural engineer competence.

b. In the Building Performance group panel, the performance of 2500 years to 100 years is automatically filled in as a result of the intersection of the hazard curve and the building capacity curve after clicking the **'Calculate Building Performance'** button
c. The '**Continue**' button is pressed to proceed to the Damage analysis stage.

4d. Damage Analysis Tab

Damage analysis is shown in Figure 4.5. No data entry is required at this stage.

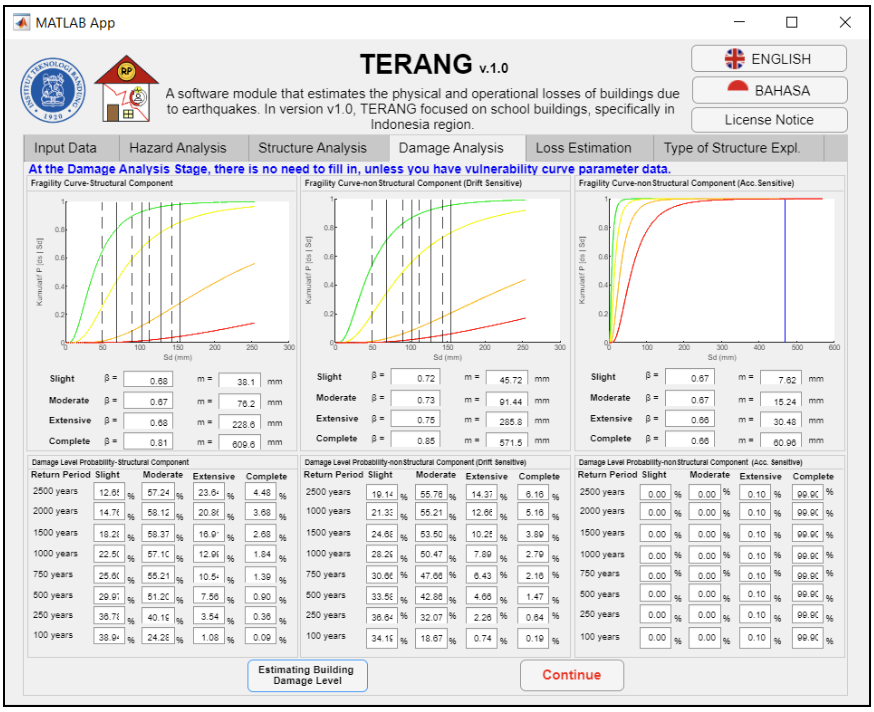


Fig. 4.5. TERANG's Damage Analysis Tab

Here are the detailed steps.

a. In the group panels Fragility curve-Structural Component, Fragility curve-Nonstructural drift sensitive Component, and Fragility curve-Nonstructural acc. sensitive Component, the median and beta values for 4 damage levels (Slight, moderate, extensive, complete) will be automatically filled in according to the input data. The median and beta parameters can be modified if the user has Incremental Dynamic Analysis (IDA) technical result data for the building. This is only recommended for advance use who have structural engineer competence.
b. In the group panel Damage level Probability-Structural Component, Damage level Probability-Nonstructural Component-drift sensitive, Damage level Probability-Nonstructural Component-Acc. sensitive is automatically filled in the results of the intersection of the building performance line against the fragility curve after clicking the 'Estimate Building Damage Level' button
c. The 'Continue' button is pressed to continue at the Loss analysis stage.

4e. Loss Analysis Tab

Loss analysis is shown in Figure 4.6. No data entry is required at this stage.

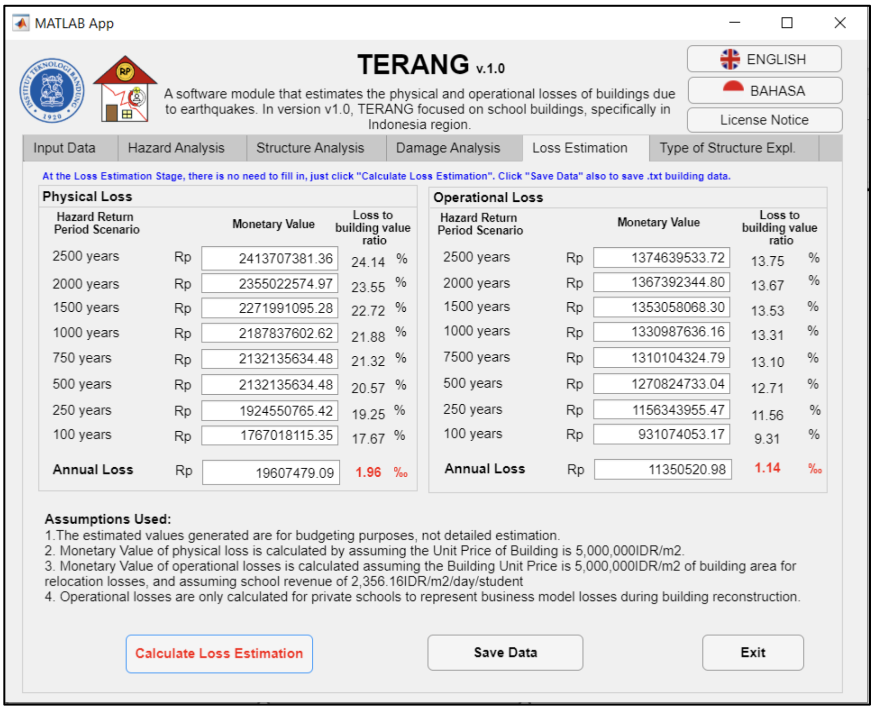


Fig. 4.6. TERANG's Loss Analysis Tab

Here are the detailed steps.

a. In the Physical Loss and Operational loss group panels, the formula calculation results are automatically filled in after clicking the **'Calculate Loss Estimation'** button.

b. Pay attention to the value assumptions used. Although there is an assumed value used for monetary value, the Loss to building value ratio is still reliable.

c. Click the '**Save Data**' button to save the building and annual loss data in a .txt file. Also send the .txt file to email terang.software@gmail.com to participate in building an opensource school building database.

d. The '**Exit**' button is pressed to exit the application.

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