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A preliminary study of seismic risk assessment shortly after the Banjarnegara Indonesia earthquake on 2018

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Abstract. This paper presents a preliminary study of seismic risk assessment in Kertosari village, Kalibening Subdistrict, Banjarnegara District, after the earthquake incident on 18th April 2018. The study was based on Hazard US (HAZUS) with Damage Probability Matrix to estimate losses of damage state with model building type (Reinforced Concrete Moment Resisting Frames-Low Height (C1L), Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms-Low Height (RM1L) and Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms (RM2L)). From the results, the probability calculation of damage in Kertosari Villages, moderate damaged category is the most. Other damage categories are slight, extensive, complete and none. Meanwhile, based on site preliminary survey and data from Banjarnegara Municipal Disaster Management Authority [1] which has updated on 20th April 2018 in Kertosari village, complete damaged category is the most. Therefore, it is necessary an expert's judgment to refine building type model and the criteria of damage state for compatible Indonesian building.

1.0 Introduction

Seismic risk assessment is the first step in disaster prevention strategy and in reducing the associated risks of infrastructures. It can define as a combination of seismic hazard and vulnerability. Seismic hazard is the event capable of causing damage while seismic vulnerability represents the degree of loss of an element resulting from hazard. In addition, seismic hazard depends on seismic zone area, and seismic vulnerability depends upon model building type, and damage state effected from the hazard. It can depict in the equation R = H x V / C, where R is a risk, H is a hazard, V is a vulnerability, and C is capacity [2,3]. It is well understood that it is not the earthquake which kills but the failure of the buildings exposed to these earthquakes [4-6]. Many researchers have been estimated and predicted vulnerability of the building by HAZUS model with the Damage Probability Matrix on damage state, there are slight, extensive, moderate, complete and none to get the most damaged [6-9]. Research on the vulnerability of buildings in developing country to predict vulnerability of the building, is still low, except Indonesia. However, the Ministry of Public Works (PU) Indonesia has been categorized damage state after the earthquake incident. Contrary, information from the building vulnerability assessment can be helpful for risk mitigation and emergency response planning and important as a based guideline to built any new building for preventing of losses. Therefore, objective of this study was to identify compatibility of the building vulnerability assessment HAZUS model with Damage Probability Matrix to estimated losses of damage state with model building type (C1L), Concrete

Frame Buildings with Unreinforced Masonry Infill Walls-Low Height (C3L), RM1L, RM2L and Unreinforced Masonry Bearing Walls (URML) in Banjarnegara District, after the earthquake incident on 18th April 2018.

2.0 Background of the study

2.1 Banjarnegara Earthquake

An earthquake incident with severe impacts had been occurred on 18th April 2018. The Meteorological, Climatological, and Geophysical Agency (BMKG) [10], had released some relevant information related to the disaster: Time of the incident Tuesday, 18 April 2018 at 13:28:35 WIB, scale: 4,4 SR, Location in 7,21°LS and 109,65°BT, Depth 4 Km. Based on the shock level map model (shake map) it is seen that the most significant shock rate occurred in Banjarnegara District on the scale of SIG-II (IV-V MMI). Meanwhile, according to community reports received BMKG show earthquake shocks felt strong enough in the Kalibening Sub-district, Banjarnegara District and surrounding areas. There were various stages of building damage, i.e. a slight damage with 88 houses, moderate damage (31), extensive and complete damage (82) [1].

2.2 Earthquake Vulnerability Assessment from HAZUS

HAZUS provide a powerful technique for developing earthquake loss estimation. This technique to use in prediction of earthquake damage and emergency response needed to deal with earthquakes, developing recovery plans for a disaster and mitigating the adverse effects of the earthquake. The vulnerability assessment component of the procedure is contained within the direct physical damage module and based on the capacity spectrum method of Applied Technology Council-40 [11]. There are factors in calculating damage probabilities of model building type using HAZUS guidelines; there are: 1). Model building type, height and seismic design level, 2). Response spectra (soil class, spectral acceleration, soil amplification), 3). The capacity curve of structure (design capacity, yield capacity, and ultimate capacity). From this factor can calculate cumulative damage probabilities, for the threshold of damage state (slight, moderate, extensive and complete) and then calculate the discrete damage probabilities to get Damage Probability Matrix.

3. Methodology

3.1 The assumption of Model Building Type from HAZUS and Development Period

Building models in America are more varied than in Indonesia. These model building types for object study are houses which just have a one-story building, so it is assumed to be in the HAZUS Low height (C1L, C3L, RM1L, RM2L, URML). Additionally, the building built after the year 1975.

3.2 Seismic Design Code

Seismic design code in Indonesia, based on the rules of HAZUS. The rule described two things, seismic zone map (American version) and development period from data research (post-1975, 1941-1975, and pre-1941). In this study, the Peak Ground Acceleration (PGA) value of the study area sourced from the Seismic Zone Map Indonesia 2017 (Figure 1), with probability value exceeding 2% in 50 years (T = 2500 years), referring to Seismic Zone Map Indonesia 2010 (Figure 2). From the seismic zone map Indonesia which established in the year 2010 and 2017 by the PU, it is seen that the value of PGA for Kertosari village (Figure 3) has the same value, that was between 0.3 - 0.4g (Figure 4). In 2011, The Ministry of Public Works-Center for Research and Development of Housing and Settlements (PU PUSKIM) had established the website-*based* application Indonesia design spectra to calculate response spectrum, based on Seismic Zone Map Indonesia 2010.
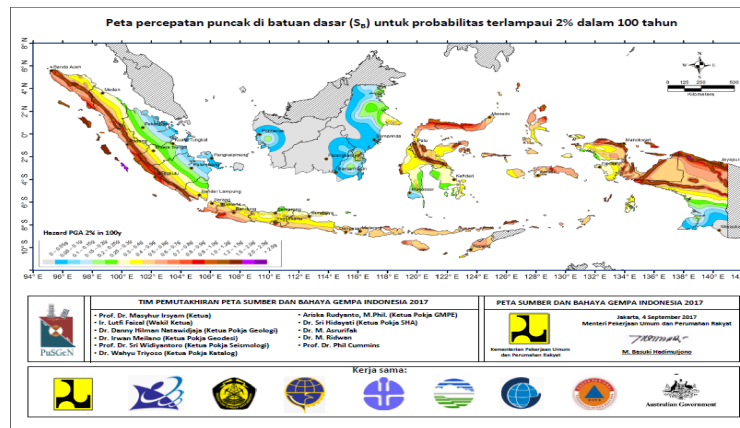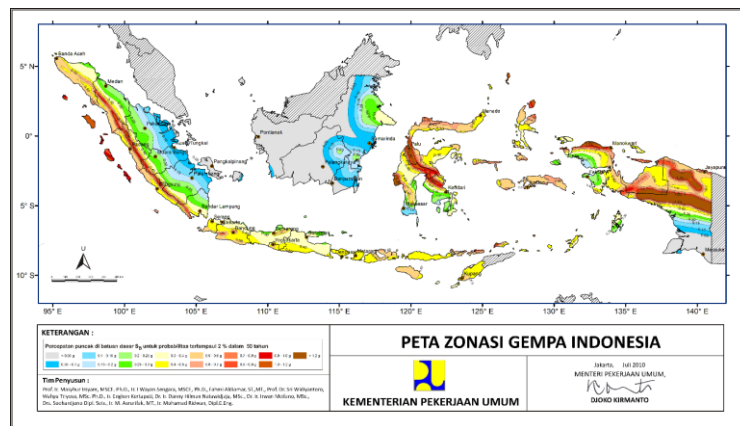
Figure 1. Seismic Zone Map Indonesia (2017) Source: [12]
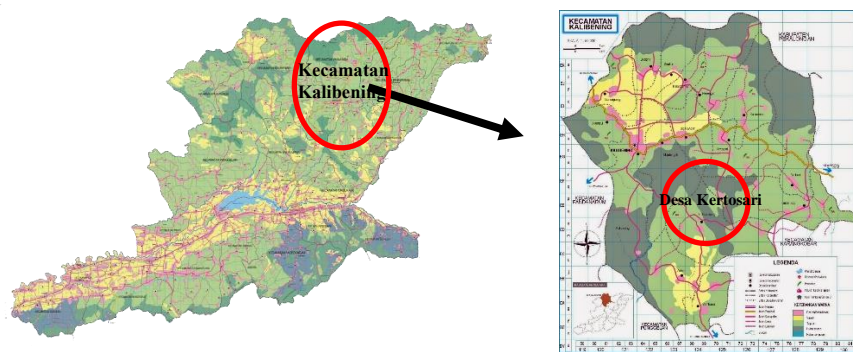
Figure 2. Seismic Zone Map Indonesia (2010) [13]

Figure 3. Kertosari Village, Kalibening Subdistrict, Banjarnegara District [14,15]

(2010)   (2017)
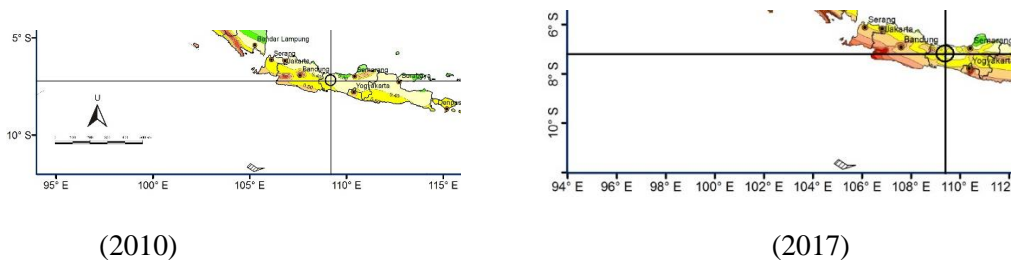
Figure 4. Comparison of seismic zone map of Kalibening Sub-district (2010 and 2017) [12,13]

3.3 Peak Spectral Displacement
Peak Spectral Displacement Value depends on:

1. a. Response spectra (the graph between T (Period) and S_A (Spectral Acceleration)), obtained from PU PUSKIM Indonesia (Figure 5).
    b. The Spectral Displacement (S_D) value obtained from Equation 1 [11]. The comparison graph between Spectral Acceleration (S_A) and Spectral Displacement (S_D) (Figure 6)

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

Where,
S_A = Spectral Acceleration (g)
S_D = Spectral Displacement (inches)
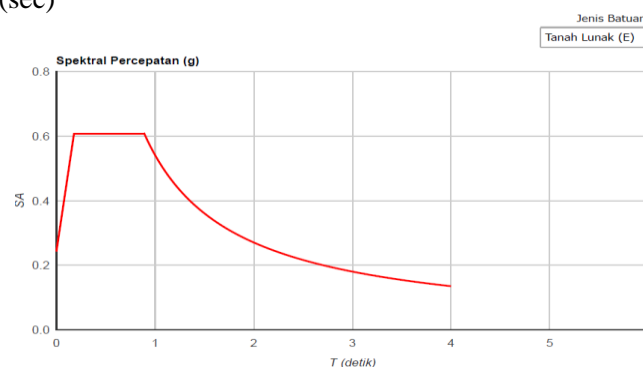T =   Time Period (sec)

Figure 5. Spectrum Response Design for all model building type of research
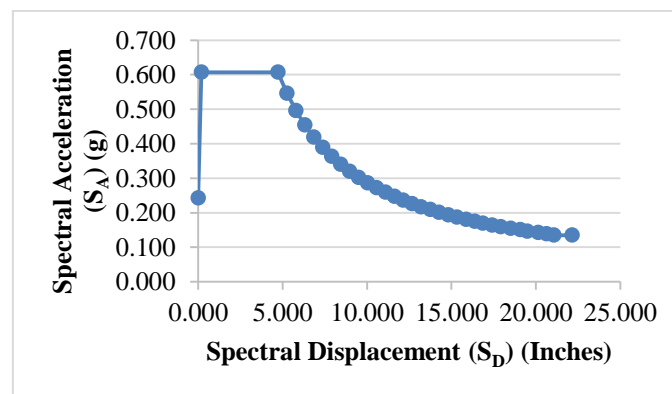

Figure 6 Ground Motion Demand Curve

2. The capacity curve of structure (design capacity, yield capacity, and ultimate capacity) was shown in Table 1 and Figure 7.

Table 1. Code Building Capacity Curves - High-Code Seismic Design Level type C1L, C3L, RML, RM2L and URML, Source: [11]

Building Type	Yield Capacity Point		Ultimate Capacity Point	
	D_y (in)	A_y (g)	D_u (in)	A_u (g)
C1L	0.39	0.250	9.39	0.749
C3L				

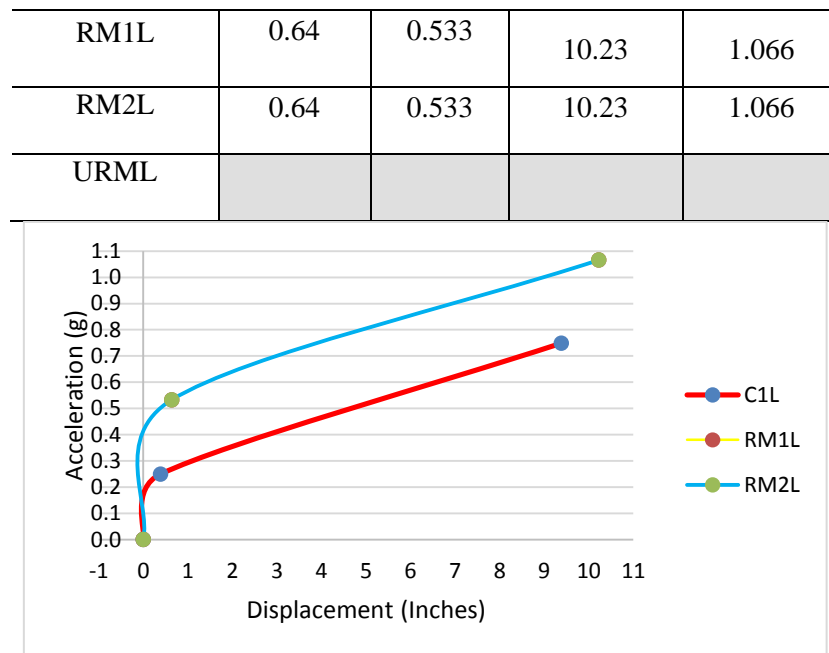|				
RM1L	0.64	0.533	10.23	1.066
RM2L	0.64	0.533	10.23	1.066
URML				

Figure 7. Capacity curve C1L, RM1L and RM2L

Peak building response (either spectral displacement or spectral acceleration) at the point of intersection of the capacity curve and demand spectrum is the parameter used with fragility curves to estimate damage state probabilities is called peak spectral displacement (S_d) (Figure 8).
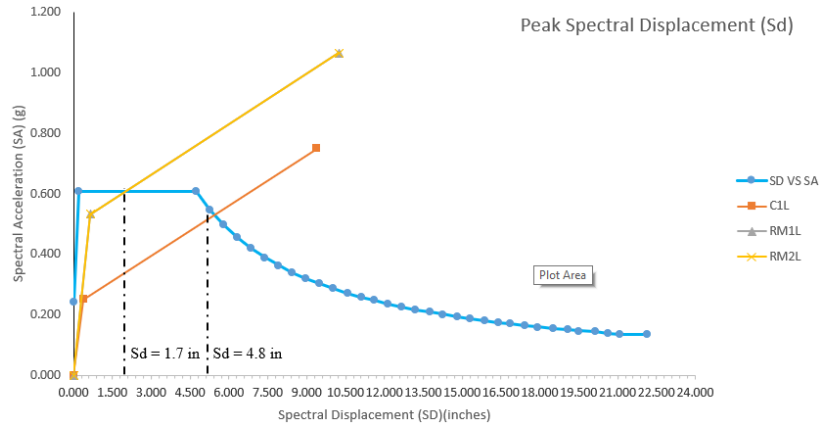

Figure 8. Peak spectral Displacement (S_d)

3.4 Damage Probability
In contrast to the research, in searching for probabilities, the damage HAZUS already has its formula. The beta and median values in HAZUS have been set according to each type of building, whereas in Indonesia the data is not available. The probability of being in or exceeding a given damage state modelled as a cumulative log-normal distribution. For structural damage, given the spectral displacement, S_d, the probability of being in or exceeding a damaged state, d_s, is modelled as Equation 2, Source: [11]

$$P[ds/S_d] = \Phi\left[\frac{1}{\beta_{ds}} \ln\left(\frac{S_d}{S_{d.ds}}\right)\right]$$

(2)

Where,

P [ds/s$_d$] = cumulative probability of damage state, ds,

$\overline{S}_{d.ds}$ = the median value of spectral displacement at which the building reaches the threshold of the damage state, ds,

β_{ds} = the standard deviation of the natural logarithm of spectral displacement of damage state, ds, and

Φ = the standard normal cumulative distribution function.

The median (S$_{ds}$) and beta (ß$_{ds}$) values based on the model building type in HAZUS. The probability value (equation 2) of such damage is logical in the form of a cumulative probability.

The discrete probabilities (probabilities of being in a given damage state) given in Equation 3 until 6 [11]

$$P_{COMB} [DS = C] = [DS \geq C] \tag{3}$$
$$P_{COMB} [DS = M] = P_{COMB}[DS \geq M] - P_{COMB}[DS \geq E] \tag{4}$$
$$P_{COMB} [DS = S] = P_{COMB}[DS \geq S] - P_{COMB}[DS \geq M] \tag{5}$$
$$P_{COMB} [DS = None] = 1 - P_{COMB}[DS \geq S] \tag{6}$$

4   Results and discussions

From the results of a preliminary survey conducted on 21st April 2018 in Kertosari village have PGA (0,326 g). The other data are shown in Table 2.

Table 2. Data from a preliminary survey in Kertosari village

Village	Photo	Building	Latitude	Longitude	Estimate Damage State (PU)
Kertosari		House 1	-7.21415	109.67872	Complete
		House 2	-7.22300	109.67012	Complete
		House 3	-7.22333	109.66958	Complete
		House 4	-7.22232	109.66930	Complete

Mostly damage state in Kertosari village is Complete Damage State; the data is getting from preliminary survey data and BPBD data which has updated on 20th April 2018.

4.1 Damage Probability

The probability of damage to buildings according to HAZUS is expressed in Equation 2 [11]. The values of Cumulative probabilities summarized shows in Table 3.

Table 3. Cumulative Probabilities

Model Building Type	Cumulative Probabilities			
	P [S I Sd]	**P [M I Sd]**	**P [E I Sd]**	**P [C I Sd]**
C1L	0.9806	0.8757	0.4455	0.0875
RM1L	0.8468	0.5765	0.1580	0.0237
RM2L	0.8586	0.5812	0.1527	0.0191

After that, and then calculate the discrete damage probabilities:

1. **C1L**
   Probability of complete damage, $\quad$ P [C] $\quad$ = P [C | SD] = 0.0875
   Probability of extensive damage, $\quad$ P [E] $\quad$ = P [E | SD] - P [C | SD] = 0.3580
   Probability of moderate damage, $\quad$ P [M] $\quad$ = P [M | SD] - P [E | SD] = 0.4302
   Probability of slight damage, $\quad$ P [S] $\quad$ = P [S | SD] - P [M | SD] = 0.1049
   Probability of no damage, $\quad$ P [None] = 1 - P [S | SD] = 0.0194

2. **RM1L**
   Probability of complete damage, $\quad$ P [C] $\quad$ = P [C | SD] = 0.0237
   Probability of extensive damage, $\quad$ P [E] $\quad$ = P [E | SD] - P [C | SD] = 0.1343
   Probability of moderate damage, $\quad$ P [M] $\quad$ = P [M | SD] - P [E | SD] = 0.4186
   Probability of slight damage, $\quad$ P [S] $\quad$ = P [S | SD] - P [M | SD] = 0.2703
   Probability of no damage, $\quad$ P [None] = 1 - P [S | SD] = 0.1532

3. **RM2L**
   Probability of complete damage, $\quad$ P [C] $\quad$ = P [C | SD] = 0.0191
   Probability of extensive damage, $\quad$ P [E] $\quad$ = P [E | SD] - P [C | SD] = 0.1336
   Probability of moderate damage, $\quad$ P [M] $\quad$ = P [M | SD] - P [E | SD] = 0.4285
   Probability of slight damage, $\quad$ P [S] $\quad$ = P [S | SD] - P [M | SD] = 0.2774
   Probability of no damage, $\quad$ P [None] = 1 - P [S | SD] = 0.1414

Generate Damage probability matrix for C1L, RM1L, RM2L, presented in Figure 9-11
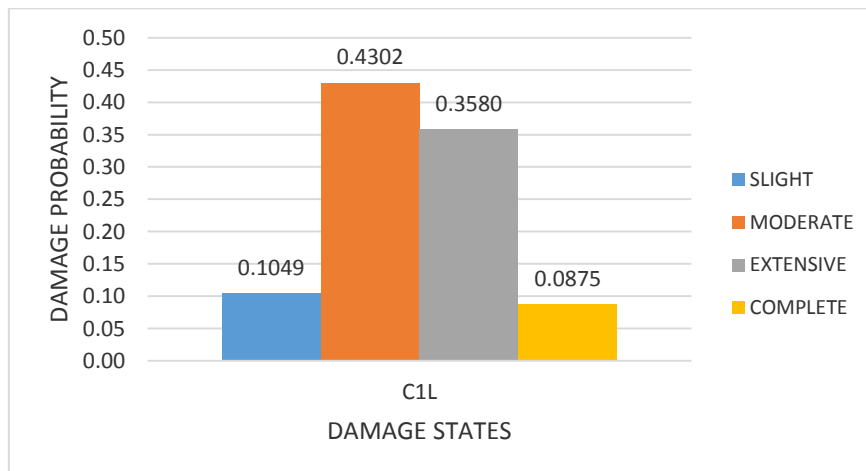

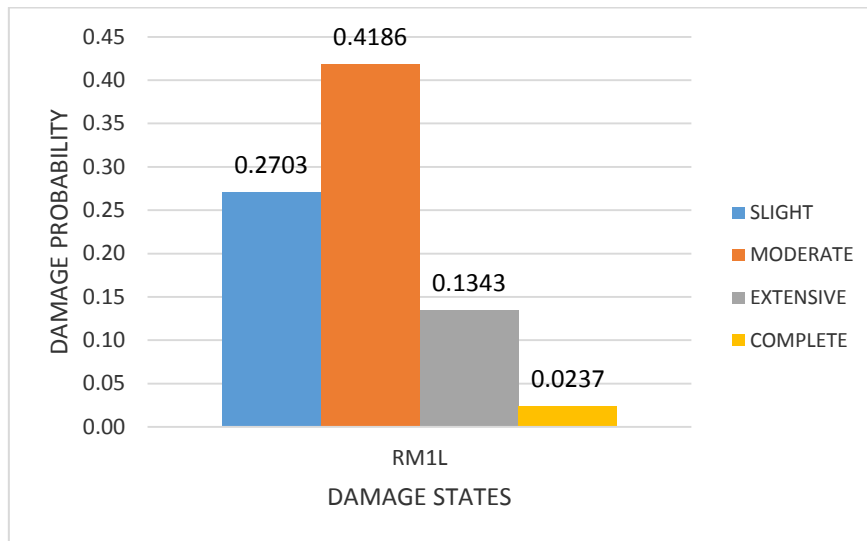**Figure 9** Damage Probability Matrix C1L

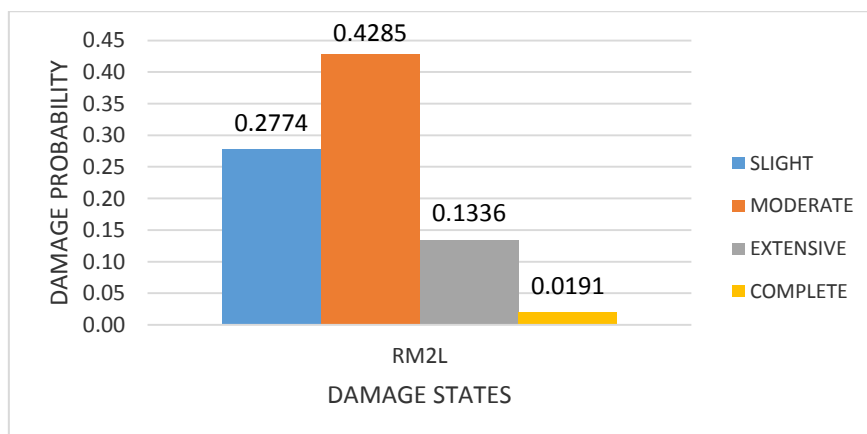**Figure 10** Damage Probability Matrix RM1L

Figure 11 Damage Probability Matrix RM2L

The Figure 9, Figure 10, and Figure 11 show the damage probabilities calculated by the HAZUS method of C1L, RM1L, RM2L model-building type in the study ward. The graph represents the damage probability of buildings having similar structural properties with C1L, RM1L, RM2L HAZUS model building type. The graph shows the buildings having C1L, RM1L, RM2 structure properties are the most vulnerable to moderate damage state and least vulnerable for C1L is to slight damage, but for RM1L and RM2L are to complete damage

5. Conclusion

The probability calculation of damage in Kertosari village, moderate damaged category is the most. Other damage categories are slight, extensive, complete and none. Meanwhile, based on a preliminary survey and data from BPBD which has updated on 20th April 2018 in Kertosari village, complete damaged category is the most. The used HAZUS with Damage Probability Matrix to estimate losses of damage state, is a cost effective and gives a quick estimate but the actual behaviour of the building may differ from the assumed capacity curve. Therefore, it is necessary an expert's judgment to refine building type model and the criteria of damage state for compatible Indonesian building.

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