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A Simplified Method for Preliminary Seismic Vulnerability Assessment of Existing Building in Kundasang, Sabah, Malaysia

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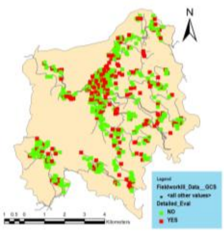
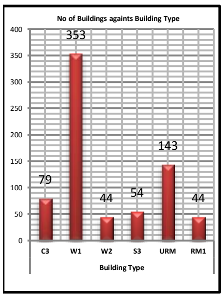
Graphical abstract





Abstract

A simplified method for preliminary seismic vulnerability assessment of existing building in particular area of Kundasang, Sabah Malaysia region is proposed. The surveys are mainly focused on building inventory such as identifying the building occupancy, building type and the storey number of buildings for study area. Rapid Visual Screening (RVS) can be effectively used to evaluate the vulnerability of large number of buildings for study area with less computational effort. The data collection form of the Federal Emergency Management Agency (FEMA 154) for RVS was gathered for this purpose. The objective of this study is to assess the vulnerable building that tendency to be further detailed analysis by the calculation of score in RVS method. Pre-assessment towards seismic vulnerability of every individual building in particular area has been assessed and the information of buildings in study region consist residential, industrial, government, school building occupancies were recorded and spatially analyzed using Geographical Information System (GIS) framework. Buildings in Kundasang are considered as less further evaluation (34%) which need have detailed analysis by modeling the structure, while another 66% considered as safe building based on rapid visual final score.

Keywords: Vulnerability assessment, Rapid Visual Screening, GIS.

Abstrak

Satu kaedah mudah bagi pra-penilaian seismik bangunan di kawasan tertentu wilayah Kundasang, Sabah, Malaysia.. Kaedah tinjauan ini terutamanya tertumpu kepada membina inventori bangunan seperti mengenal pasti penghunian bangunan, jenis bangunan dan bilangan tingkat bangunan bagi kawasan kajian. Pemeriksaan Visual Pesat (RVS) boleh digunakan dengan berkesan bagi menilai kelemahan sebilangan besar bangunan bagi kawasan tertentu dengan kaedah yang kurang pengiraan. Objektif kajian ini adalah untuk menilai bangunan berpontesnsi kecenderungan untuk dianalisis lebih terperinci dengan pengiraan skor dalam kaedah RVS . Bangunan di Kundasang dianggap sebagai kurang (34%) yang memerlukan analisis terperinci oleh pemodelan struktur, manakala selebihnya lagi dianggap bangunan selamat 66 % berdasarkan faktor oleh seni bina. Semua pangkalan data bangunan direkodkan dan dianalisis dengan menggunakan Sistem Maklumat Geografi rangka kerja (GIS).

Kata Kunci: Kelemahan bangunan, Penilaian Visual Rapid (RVS), GIS.

■1.0 INTRODUCTION

Malaysia has been categorized under low seismicity area. Consequently, earthquake resistant design has not been given as emphasis until a decade ago when the Malaysian lawmakers were briefed by Meteorological Department (MMD), in 2002, on the distant of shock waves of the 2001 Gujarat earthquake, which travelled 600 km from its epicenter to rock and cause devastation to many cities in India [1]. Since 2005, the government of Malaysia has taken various efforts, through the Ministry of Science, Technology and Innovation (MOSTI), to assess the risk associated with potential earthquake events. A report from MMD, a weak earthquake has occurred with magnitude 4.8 Richter scale in Pekan Ranau, Sabah at 7:35pm on 01 February 2014.The earthquake epicenter is located at latitude 6˚10' N and longitude 116˚ 45'E, 16 km Northeast of Ranau, Sabah. Tremors felt near Ranau, Sabah. Most people perceive that Malaysia is free from life-threatening seismic crisis. In reality, seismic hazard in Malaysia is irrefutable, with seismic hazard originating from seismically active neigbouring countries such as Indonesia and Philippines [2].

In the past, Kundasang region has been jolted by moderate earthquake events as reported in MMD database. The study area is located at Kundasang, Sabah, Malaysia. It lies from latitude 5˚ 58' N to 6˚ 00' and longitude from 116˚ 33' E to 116˚ 36'E and the covered area about 22.2 km. Kundasang owes its moderate seismicity condition to the active Mensaban and Lobou-Loubo faults zones, which have brought about earthquake that cause light damages to infrastructures such as road and bridge [3]. This region has been identified as a potential site for a future catastrophic earthquake and has already witnessed seismic events of lower magnitude in recent past. These earthquakes have demonstrates that the seismic vulnerability of the building stocks in the region was primarily responsible for a large number of human casualties [4]. Most of the buildings in the region are non-engineered and awareness and knowledge among the masses is lacking regarding earthquake-resistant construction technique in areas of high seismic vulnerability. Inadequate building by law and lenient regulatory regimes only contribute to the problems. There is a need to assess the vulnerability of building stocks in such seismically active area. Due to non-availability of enough building inventory data for seismic vulnerability assessment, a procedure based on fieldwork called Rapid Visual Screening (RVS) is found to be suitable and has been illustrates using Geographical Information System (GIS) in term of building occupancy [5].

Vulnerability is often represented by the probability of reaching or exceeding different damage state for a specified hazard scenario. Vulnerability can be briefly defined as ‘being prone to or susceptible to damage or injury’ [6]. To determine vulnerability, a long chain of causes or factors can be analyzed, and among them, natural, technological, social and political are the salient factors. The assessment of vulnerability to estimate the seismic risk requires particular information on each one of the factors and elements at risk. All items, like geologic evolution, urban development, strength of structures and possible collateral effects, have to be considered carefully to assess as accurately as possible the seismic vulnerability of a site. Seismic vulnerability can be measured either qualitatively or quantitatively [7]. The qualitative measure of assessment can be carried out by classification of damages to various types of constructions using different earthquake intensity scales Modified Mercalli Index (MMI). Another way of making qualitative measures of vulnerability is in terms of damage states [8]. A specified ward in Kundasang (Figure 1) was developed as boundary of study. The inventory data needed for vulnerability assessment of houses and buildings in study ward were gathered using simplified form, in order to carry out an extensive survey.

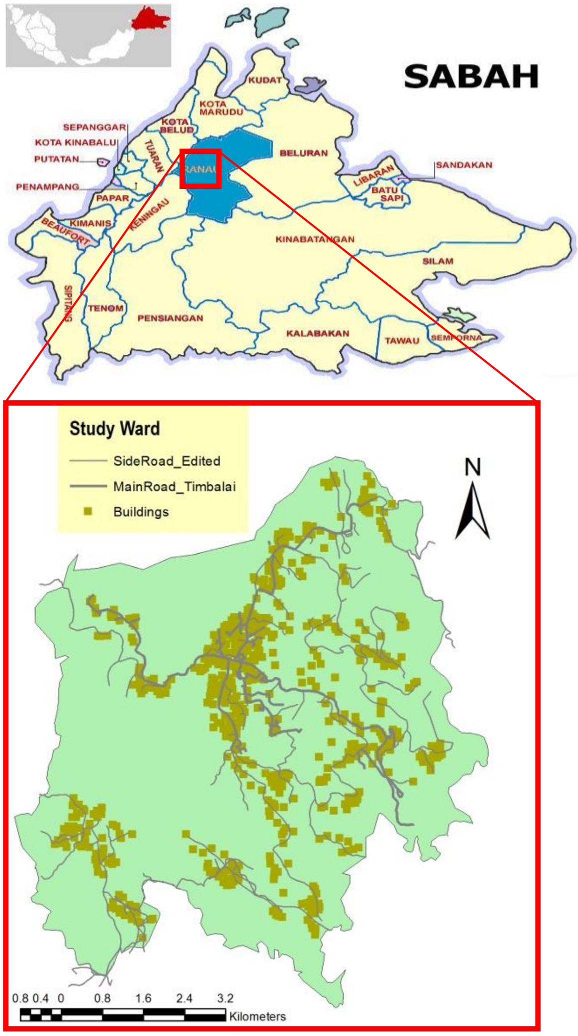


Figure 1 Buildings, main roads and side roads in study ward.

■2.0 METHODOLOGY

2.1 Building Inventory

Building Inventory was conducted during the fieldwork. These include residential, commercial, industrial, religious, government, emergency, history and education as building occupancy data. The limitation on building inventory was carried out only for particular area in Kundasang. Figure 2 shows example of buildings in Kundasang in term of building occupancy. The data collection was prepared taking into consideration of five (4) main types of construction practice within the ward which are Reinforced Concrete (RC), brick, wood (Wood for housing,W1 and Wood For Commercial use, W2) and steel (Steel Frame Building,S3) as shown in Table 1.

Figure 3 illustrates the information such are occupancy classes (Residential) and structure type (W1) required in the rapid visual form in order to assess vulnerable buildings in study area. Building databases are stored in Geographical Information System (GIS) framework. GIS integrates extremely diverse data and various tool into common framework for analysis, cooperation and decision making [9]. The development of GIS system involves detailed information that facilitates disaster preparedness, mitigation, rehabilitation and reconstruction or even rescues operations [10].

Figure 2 Building occupancy in study ward area in Kundasang, Sabah. Residential (top left), Education (top right), Government (down left) and Religious (down right).

Table 1 Description of building types in Kundasang

Category	Building Type	Description
Reinforcement Concrete (RC)	C3	Concrete Frame
Brick	RM1	Reinforcement Masonry
	URM	Unreinforcement
Wood	W1	Wood for housing
	W2	Wood for commercial
Steel	S3	Steel Frame

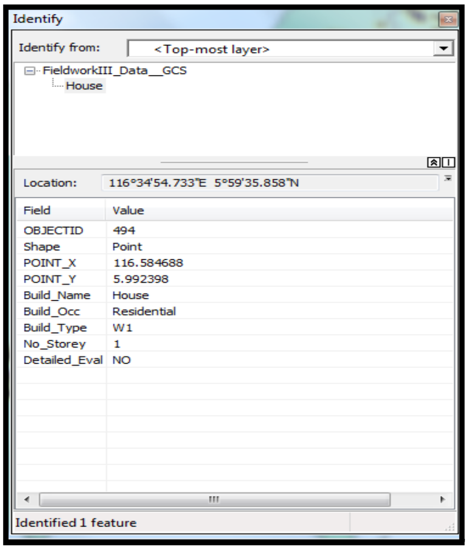
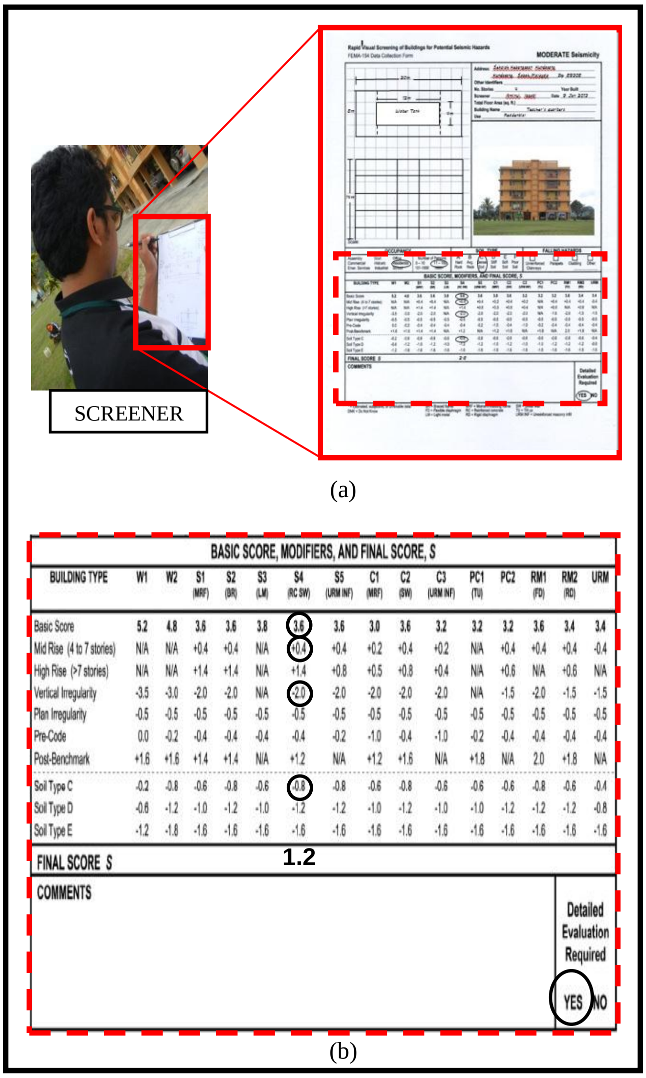


Figure 3 Buildings identity in Kundasang ward

2.2 Rapid Visual Screening (RVS)

The Rapid Visual Screening (RVS) method was designed to be applied without performing any structural calculations. The procedure utilizes scoring systems that require the trained evaluator. The inspection, data collection and decision making processes typically occurs at the building site. The total duration for the processes was expected to take approximately 20 minutes for each building based on numerical seismic hazard and vulnerability score [11].

Detailed seismic vulnerability evaluation is a technically complex procedure and can only be performed on a limited number of buildings. Thus, it is very important to use simplified procedure that can help to rapidly evaluate the vulnerability profile of different types of buildings, so that the more complex evaluation procedures can be limited to the most critical buildings [12] To assess the buildings within the surveyed area, the RVS method as suggested by Federal Emergency Management Agency is used [13].



BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	5.2	4.8	3.6	3.6	3.8	3.6	3.6	3.0	3.6	3.2	3.2	3.2	3.6	3.4	3.4
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

Figure 4 Moderate seismicity FEMA 154 form (a) Basic Score Modifier for rapid visual screening (b). [14]

Basic Structural hazard scores for various building types are provided in the RVS form. Figure 4(b) demonstrates the screener modifies the basic structural hazard score by identifying and circling score modifiers which are then added (or subtracted) to the basic structural hazard score to arrive at a final structural score, S. The basic structural hazard score, score modifiers and the final structural score S, are all related to the probability of building collapse [15]. The result of the screening procedure is a final score that may range above the basic score, with a high score indicating good expected seismic performance and a low score indicating a potentially hazardous structure. While the score is related to the estimated probability of major damage, it is not intended to be a final engineering judgment of the building, but merely to identify buildings that may be hazardous and require detailed seismic evaluation. If the score is 2 or less, a detailed evaluation is recommended. On the basis of detailed evaluation of engineering analysis through detailed procedures, final determination of seismic adequacy for rehabilitations can be made.

3.0 RESULTS AND DISCUSSION

3.1 Building Occupancy

The areas covered under the survey are located in Kundasang region. The survey was mainly focused on identifying building classification, building type, plot size and shape, clear distances from surrounding structures and basic information of the building. Digital photographs of each building from at least two directions were taken. A database was compiled in Geographical Information System (GIS) attribute table. There are approximately 717 structures in the surveyed areas of Kundasang which differ in term of the type of buildings, occupancy of buildings and number of storey.

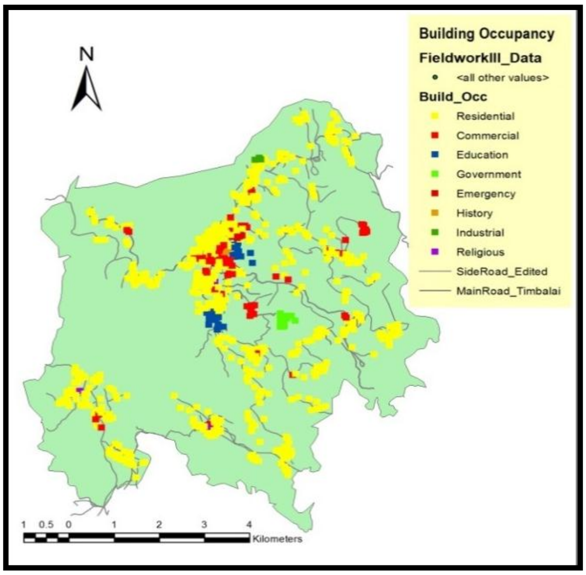


Figure 5 Building Occupancy based on Field work III.

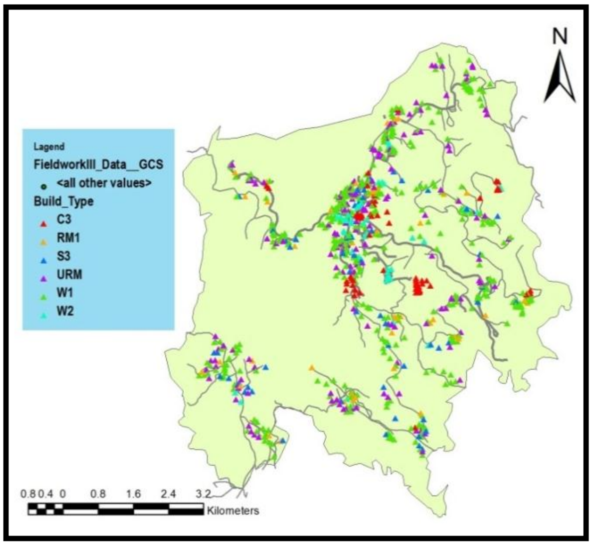


Figure 6 Building Type based on Field Work III.

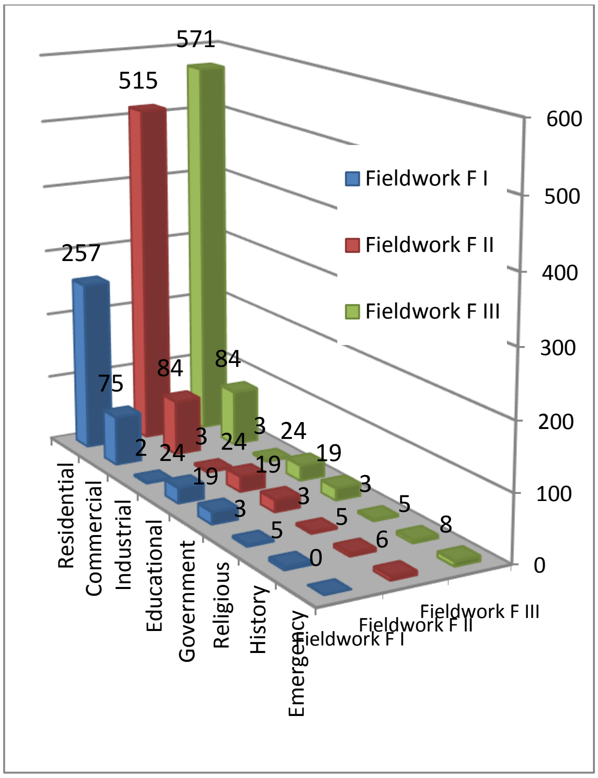


Figure 7 The numbers of building against Building Occupancy based on fieldwork.

Figure 5 shows the building occupancy in study ward regarding on latest field work (F III). All the information provided are illustrated and managed in Geographical Information System (GIS) attribute table. Figure 6 shows the building occupancy in study ward regarding on latest field work (F III). All the information provided are illustrated and managed in GIS attribute table. The bar chart shown in Figure 7 illustrates the total number of buildings in term of building occupancy respectively. Based on bar chart, the highest number of buildings are in term of occupancy are the residential building (571) followed by commercial buildings. This is because Kundasang is categorized as rural area which has tourism and agriculture as main attraction. Figure 8 shows the relation between numbers of buildings with building types (such as C3, W1, W2 S3, URM and RM1) and W1 type is the majority in Kundasang. The figure indicates that most of Kundasang areas are populated with villagers while other types of buildings such as C3 are comprised mainly of school buildings, hotels and government buildings.

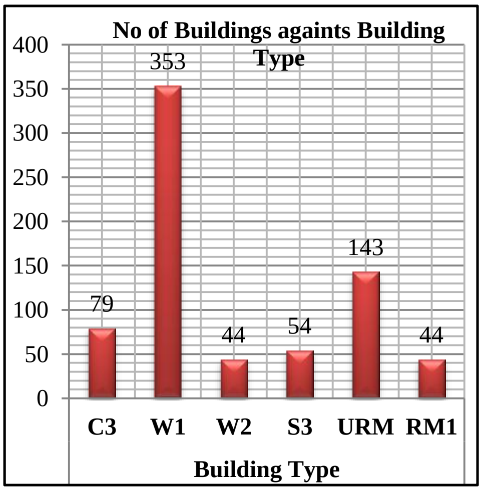


Figure 8 The numbers of building against building type.

Figure 9 illustrates the number of buildings according to the number of storey. About 711 (99.2%) of buildings in Kundasang are categorized as low rise, 5 (0.7%) are mid-rise buildings of 4-6 storey while only 1 (0.1%) equal or exceed 7 storeys.

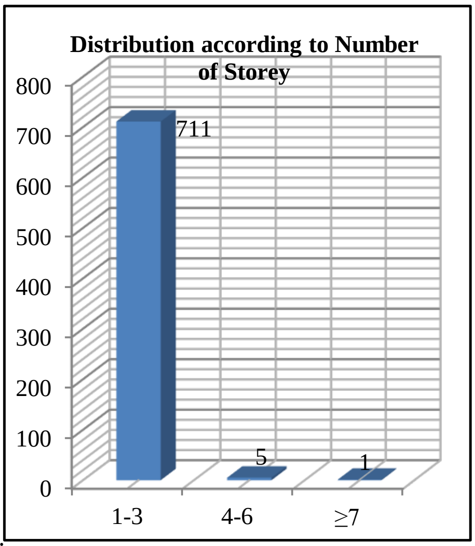


Figure 9 Relation Between number of buildings and number of storey.

3.2 Rapid Visual Screening Score Sheet, Analysis and Uses

The damage potential can be estimated based on Rapid Visual Screening (RVS) score as given in Table 2. However, it should be realized that the actual damage will depend on a number factors that are not include in RVS procedure. As a result, this table should only be used as indicative to determine the necessity of carrying out simplified vulnerability assessment of buildings.

Table 2 Structural Scores with Damage Potential

RVS Score	Damage Potential
S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 2.5	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 2.5	Probability of Grade 1 damage

Table 3 shows the result of RVS based on type of building in Kundasang. Most of the buildings in Kundasang are of the residential type (571, 79.6%), out of which 183 (32%) are hazardous while 388 (68%) are non-hazardous.

This is followed by commercial type (84, 11.7%), out of which 33 (39.3%) are hazardous while 51 (60.7%) are considered non-hazardous. Both the residential type and commercial type which are considered hazardous have a similar characteristic both in that have vertical irregularities in term of shape. History type of buildings (6, 75%) shown highest percentage out of which 4 (80%) are hazardous while 1 (20%) considered non-hazardous. This is because most of the buildings are built with weathered unreinforced masonry.

Figure 10 demonstrates the RVS result using GIS based tool to locate the building which require further investigation.

The result obtained from RVS shows the location of buildings that need further investigation, for which based on Table 10, the total structural score less than 2 (S< 2) in Kundasang area is lower (34%) than no need further investigation which is 66% that score exceeding 2.5 (S>2.5). Figure 11(a) provides the number and percentage of hazardous and non-hazardous in study area respectively while figure 11(b) shows the composition of the hazardous buildings. About 183 (75.6%) considered hazardous buildings which is influenced by close proximity to the hill sides followed by commercial buildings (33, 13.6%), education buildings (10, 4.13%), government buildings (5, 2.1%), emergency buildings (6, 2.5%), History buildings (4, 1.7%), Industrial buildings (1, 0.4%), Religious buildings (0, 0%)

Table 3 Cumulative results of buildings from rapid visual screening

Building Occupancy	Number of Buildings	Percentage Buildings per Area	Number of Detailed Evaluation Buildings	
		(%)	YES (Hazardous)	NO (Non-Hazardous)
Residential	571	79.6	183	388
Commercial	84	11.7	33	51
Educational	24	3.3	10	14
Government	19	2.6	5	14
Emergency	8	1.1	6	2
History	5	0.7	4	1
Industrial	3	0.4	1	2
Religious	3	0.4	0	3
TOTAL	**717**	**100**	**242**	**475**

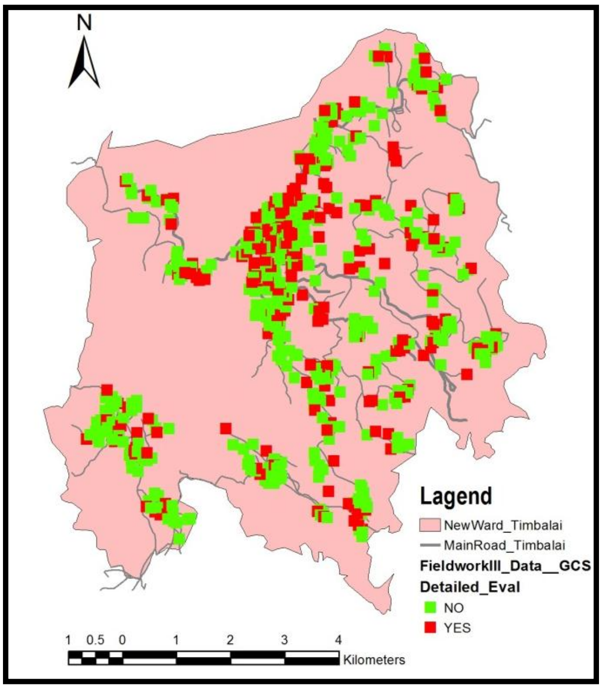


Figure 10 Map of buildings detailed evaluation based on RVS.

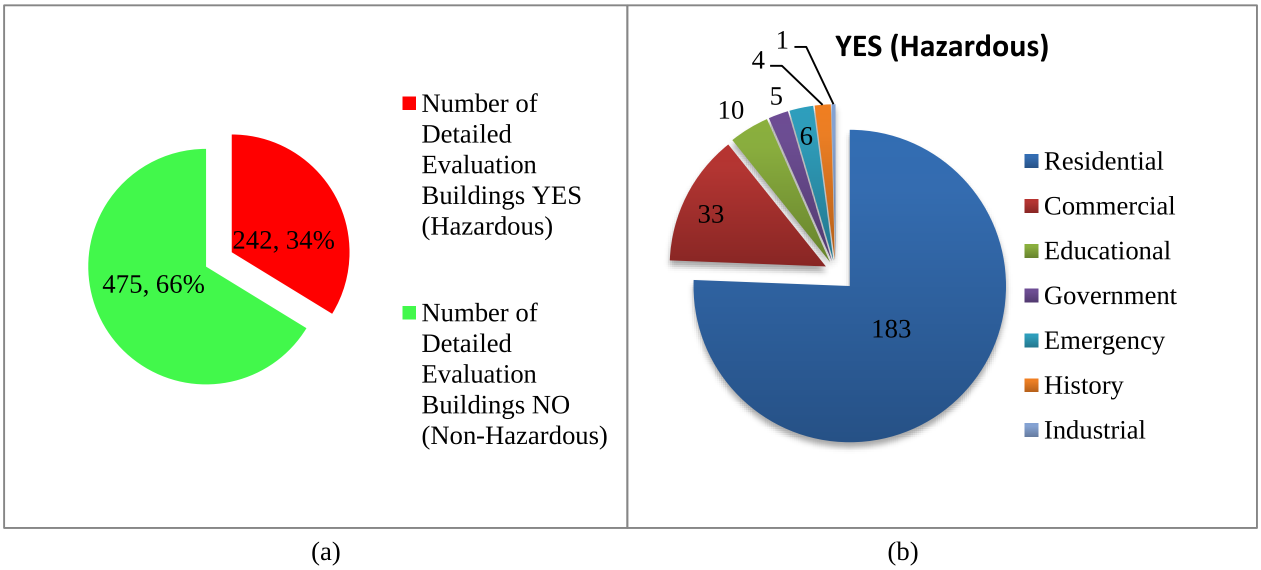


Figure 11 Number and percentage of hazardous and non-hazardous building respectively (a) Composition of the hazardous building in Kundasang (b)

■4.0 CONCLUSION AND RECOMMENDATION

The identification of seismically vulnerable of buildings is necessary first step in developing effective disaster mitigation programs for the country. This study has shown that most of the residential buildings in Kundasang have low vulnerability level due to earthquake impact. Rapid Visual Screening (RVS) method is one of the effective building assessments tools, owing to its analyzing speed, user-friendliness, and low cost. From the assessment by RVS method, the structure score was produced based on five main aspects, namely the seismic region type of soil, type of building, building classification, vertical and plan irregularity. Geographical Information System (GIS) integrates extremely diverse data and various tools into a common framework for analysis, cooperation and decision making. The development of GIS system involves detailed information that facilitates disaster preparedness, mitigation, rehabilitation and reconstruction or even rescues operations. 34% of the buildings score lower than 2 (S<2) indicate detailed analysis needed for further evaluation, while another 66% of building in study ward can be marked as safe buildings because score more than 2.5 (S>2.5) that show the probability of grade 1 damage is slight damage. The low numbers of building needed to be further analyzed show that the buildings in Kundasang area tend to collapse when subjected to earthquake excitation. The structures that needed to be further evaluated have to be modeled in structural analysis software to define vulnerable target element of individual buildings instead of able to simulate earthquake scenario.

Acknowledgement

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References

[1] Bendick, R., Bilham, Fielding, R.E., Gaur, V., Hough, S.E., Kier, G., Kulkarni, M.,Martin, S. and Mukul, M. 2001. The January 26. Bhuj India earthquake. *Seismological Research Letter.* 73(3).

[2] Adnan, A.,Hendriyawan, A. Marto,and I.Masyhur. 2005. Seismic Hazard Assessment for Peninsular Malaysia using Gumbel Distribution Method. *Jurnal Teknologi*. 42: 55–73

[3] Sherliza ZAINI SOORIA, Sumio SAWADA and Hiroyuki GOTO. 2012. Proposal for Seismic Resistant Design In Malaysia: Assessment of Possible Ground Motions in Peninsular Malaysia. *Annual of Disas.Res. Ins.* No. 55B. Kyoto University

[4] Taksiah Abdul Majid. 2009. *Less Than One Percent Of Building Malaysia Have Earthquake Preventive Measure.* http://www.bernama.com.my/bernama/v5/newsindex.

[5] Steven M. Vukazich, Guna Selvaduray, Jessica Tran. *Conducting a Soft First-Storey Multi Family Dwelling survey*. An Example using Santa Clara County, California

[6] Blaikie P., Cannon T., Davis I., and Wisner B. 1994. *At Risk: Natural Hazards, People's Vulnerability, Disaster.* 2nd Edition. London: Routledge.

[7] Dowrick D.J. 2003. *Earthquake Risk Reduction*. UK: John Wiley & Sons.

[8] Sucuoglu, H, And Yazgan, U. 2003. Simple Procedure for Seismic Risk Assessment in Urban Buildings Stocs. Seismic Assessment and Rehabilitation of Existing Buildins. *NATO Science Series*. IV/29: 97–118. Editors: S.T. Wasti and G. Ozcebe, Kluwer

[9] Calvi, G.M., Pinho, R., Magenes, G., Bommer, J.J Restrepo-Velev and Crowley, H. 2006. Development of seismic vulnerability assessment methodologies over the past 30 years. *ISET Journal of Earthquake Technology*

[10] Guragain, J. 2004. *GIS for Seismic Building Loss Estimation: A Case Study from Lalitpur Sub-Metropolitan City Area, Katmandu, Nepal*.84. M. Sc. Thesis. Enschede.

[11] FEMA 154. 2002. *Rapid Visual Scrrening of Building for Potential Seismic Hazards*. A Handbook, 2nd edn. Redwood City, CA.

[12] Sinha R., and Goyal A. 2004. *A National Policy for Seismic Vulnerability Assessment of Buildings and Procedure for Rapid Visual Screening of Building for Potential Seismic Vulnerability*. Proposed National Policy on Seismic Vulnerability Assessment of Buildings, Mumbai, India.

[13] FEMA, Federal Emergency Management Agency. 2012. *HAZUS-MH 2.1: Technical Manual*. Washington DC: FEMA.

[14] Ghafar, N., Ramly, M., Alel and A., Adnan. 2013. Preliminary Seismic Vulnerability Assessment of Kundasang, Sabah, Malaysia. *9th International Conference on Geotechnical and Transportation Engineering*. Persada Johor International Convention Center, Johor Bharu, Malaysia.

[15] ATC. 2002. *Rapid Visual Screening of Buildings for Potential Seismic Hazards*. Supporting Documentation (2nd edition), prepared by the Applied Technology Council for the Federal Emergency Management Agency, FEMA 155bReport, Washington, D.C.