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Re-evaluation of Building Collapse Risk in Yangon Based on Obtained Dataset by Field Surveys

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Abstract

Myanmar has been increasingly thriving since the civilian government led by President U Thein Sein was established in 2011. However, similar to other Southeast Asian countries, it is vulnerable to natural disasters such as cyclones, floods, and earthquakes. Myanmar is at the greatest urban disaster risk for earthquakes. This is largely due to several populated, major cities such as Mandalay, Naypyidaw, Bago, and Yangon developed along the Sagaing Fault—a continental transform fault between the Indian and Sunda plates. In the 20th century, 9 earthquakes at or above 7.0 magnitude have occurred along the fault.

The authors have been involved in the SATREPS project "Development of a Comprehensive Disaster Resilience System and Collaboration Platform in Myanmar" since 2014 and were responsible for developing a vulnerability map in terms of building collapse risk for Yangon as the earthquake-related disaster group. However, Yangon City has not catalogued enough data for the assessment. Then, we tried to evaluate its building collapse risk with existing ground condition data which was published in 1934, and vulnerability functions for Japanese buildings developed by the actual building damage dataset due to the 1995 Great Kobe Earthquake [5]. As the final period of the project, we had obtained site amplification and building vulnerability functions based on field surveys in Yangon, pull-over loading tests of hut buildings, and numerical method.

The results are clarified as follows:

(1) The maximum building collapse risk value became 78.90 in 12th Ward in Yankin Township and the minimum value became 0.00. Four wards out of the ten worst wards are located in Dawpon Township.

(2) Although the comparison of building collapse risk value in our previous research and this study indicates high correlation coefficient by 0.70, building collapse risk value of this study is about three times higher than the previous version in the wards. There seem two reasons of this result: (i) The amplification used in this study, as a result of field surveys, became higher than the previous one; (ii) The actual building vulnerability in Yangon is higher than that used in the previous study based on Japanese case.

(3) Building collapse risk map (Ver. 3.0), namely urban vulnerability map in terms of building collapse risk, was made.

(4) Totally, 412 wards (72.3%) were in the same ranking both in the previous and this study. It means that we could evaluate building collapse risk in Yangon with 72.3% accuracy based on temporal datasets even if we don't have enough information on building vulnerability functions and site amplification.

Keywords: urban vulnerability, Myanmar, vulnerability function, ground condition, building structure

1. Introduction

Assessment of urban vulnerability is one of the important factors for urban development, especially for the cities which are rapidly urbanized such as Yangon, Myanmar. The authors have been involved in a SATREPS project, "Development of a Comprehensive Disaster Resilience System and Collaboration Platform in Myanmar [1]," since 2014 and been researching on making a vulnerability map in terms of building collapse risk for Yangon as the earthquake-related disaster group. However, there are several problems to set it forward as Murao et al. pointed out [2]. Table 1 shows 7 research questions which we faced in the project.

Table 1 – Research questions in making vulnerability maps for Yangon City

	Research Questions
RQ.1	How can we get the information of soil conditions and classification in Yangon City?
RQ.2	What is proper administrative unit for damage analysis?
RQ.3	What area will be covered for the assessment?
RQ.4	How can we classify the buildings for the assessment?
RQ.5	Which districts are appropriate for collecting building data?
RQ.6	How can we develop vulnerability functions (fragility curves)?
RQ.7	What ground shaking is estimated?

Yangon City has not catalogued enough data for the assessment so far. In order to understand and to arrange regional building characteristics of the city, Murao et al. [3] explored the possibility of using digital building model (DBM) data obtained from remote sensing imageries for the urban vulnerability assessment. Later, our group reported a procedure to assess urban vulnerability, namely how the authors had made a tentative building collapse risk map of Yangon using available datasets, such as simple ground condition data [4, 5].
Several research members in the earthquake-related disaster group in the SATREPS project had forwarded to solve those research questions during the period of the project. This paper aims to evaluate present urban vulnerability focusing on building collapse risk using the latest datasets as a result of continuous surveys conducted by the members in Yangon.
This paper is a reworked and more detailed version of the author's presentation at the 19th International Symposium on New Technologies for Urban Safety of Mega Cities in Asia [6], updated with data as of January 2020.

2. Method

The evaluation of building collapse risk in this project, namely how to make a vulnerability map, follows the community earthquake risk assessment conducted by Tokyo Metropolitan Government (TMG) that has forty-year history [7]. The community earthquake risk assessment is a relative evaluation method that compares regional differences in urban risk. This assessment has two main purposes: (1) to be useful for local government officials' decision making with regional priorities for urban safety strategies, and (2) to improve risk awareness and understanding of living environment for residents. The most recent issue, the 8th edition, was released in March 2018 [8].

Building collapse risk is defined as a measure of the danger of buildings collapsing or tilting due to shaking from an earthquake. This risk is measured according to the type of buildings in the community and ground soil classification.

The following procedure is taken for the assessment here according to TMG method. The process of building collapse risk assessment with the research questions and an additional explanation related to the assessment are illustrated in Fig. 1.

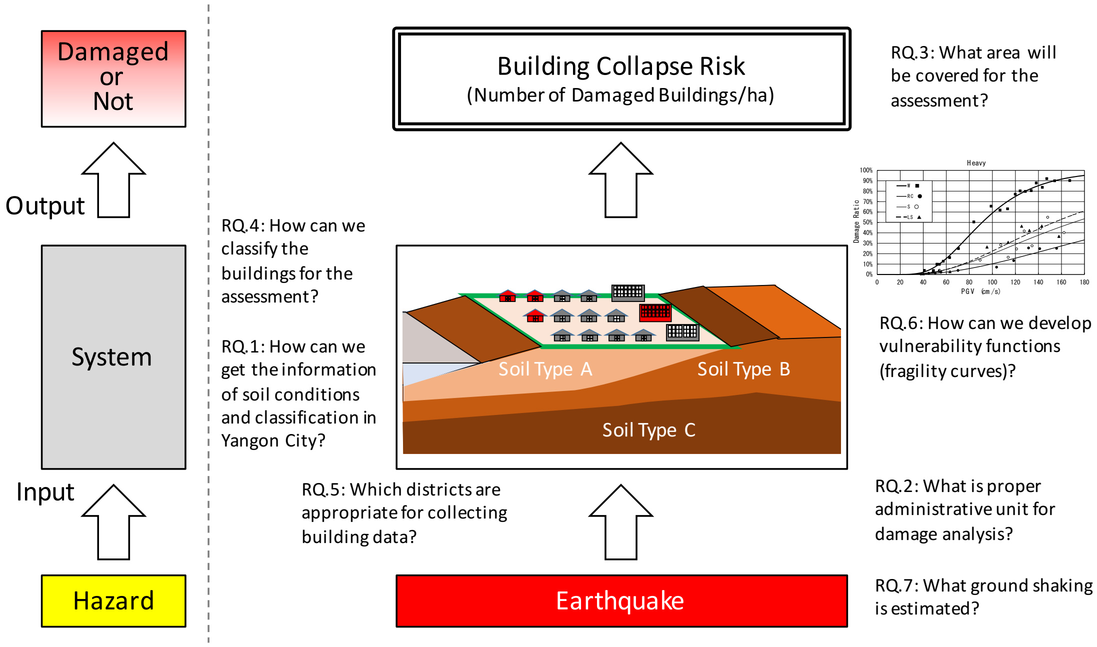


Fig. 1 – The process of building collapse risk assessment

3. Building Collapse Risk Evaluation in Yangon

Calculating building collapse risk is a six-step process, which is detailed in Fig. 1. The steps taken in the study are explained below, referring to our past research [5].

3.1 Setting administrative units and base maps

Building collapse risk value is a measure of the number of buildings collapsing or tilting following an earthquake per 10,000 m^2, and it was calculated according to administrative units, named cho-cho-moku in Japan, in the TMG method [7]. Yangon consists of 33 townships [9], and each township encompasses tens of own wards that residents are familiar with in their daily lives. This study uses "ward" as the administrative unit to answer RQ.2 "What is proper administrative unit for damage analysis?"

Visualization of analysis or assessment in each step needs a base map. JICA prepared a GIS-based map for the fact-finding survey in March 2012 [10], and this study utilized this map system, which was possible through JICA's support.

3.2 Use of available building inventory data

Building inventory comprises a critical dataset for building collapse risk evaluation. This study utilized a dataset compiled in July 2016 that was provided by YCDC.

This building inventory was arranged for each ward in each township, exhibiting convenient organization for data processing in this study. It includes the number of buildings, number of stories, and structural types. The building structure is classified into 9 types: (a) hut, (b) wood, (c) brick-nogging, (d) RC with steel, (e) steel, (f) timber with CGI sheet roofing, (g) timber, (h) RC, and (i) roadside shop. This is the answer to RQ.4 "How can we classify the buildings for the assessment?"

According to our previous research [5], the number of wooden buildings was the highest at 244,876, followed by RC. These structural types accounted for 93.8% of all buildings in Yangon. The 3rd most common building type was brick-nogging, but this type comprised only 3.1% of buildings in the city.

Finally, after examining the data, we identified 432,723 buildings in 567 wards of 33 townships. Fig. 2 shows the building distribution in the objective wards examined in this study. This also responds to RQ.3 "What area will be covered for the assessment?" and RQ.5 "Which districts are appropriate for collecting building data?"

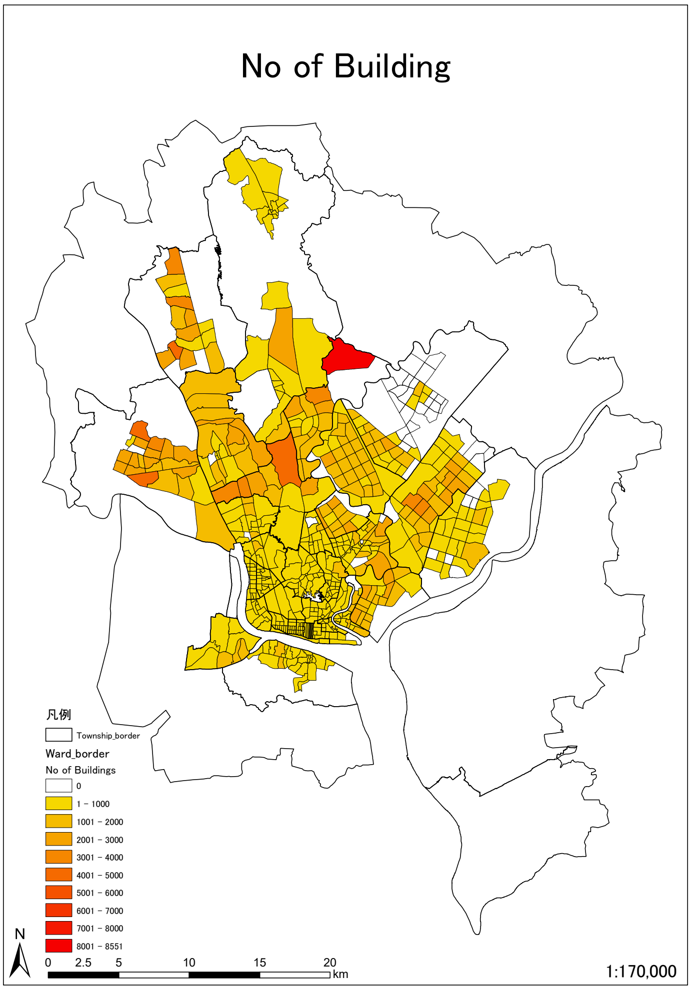


Fig. 2 – Building distribution in Yangon City [5]

3.3 Site amplification

When we started the SATREPS project, the information of soil conditions was not sufficient to cover the whole city of Yangon. Then, we used a geological map of Yangon demonstrated by Aung [11] based on Chhibber's research [12]. Fig. 3 shows the ground condition classification in our previous research [5]. There are four ground conditions for the objective areas: (1) Alluvium (Qal), (2) Valley-filled deposits (Qvd), (3) Danyingon clays (T-pd), and (4) Azanigon sandrocks (T-pa). In the previous research, the amplification used in the TMG method [8] was adopted after checking the similarity of soil conditions between Tokyo and Yangon.

In 2019, the authors often conducted field surveys to understand ground conditions and to calculate the site amplification distribution. Fig. 4 and Fig. 5 are the comparison of site distribution and amplification based on previous research and our field surveys. The result of the field surveys is used for this study. Fig. 4(b) is also the answer of RQ.1 "How can we get the information of soil conditions and classification in Yangon City?"

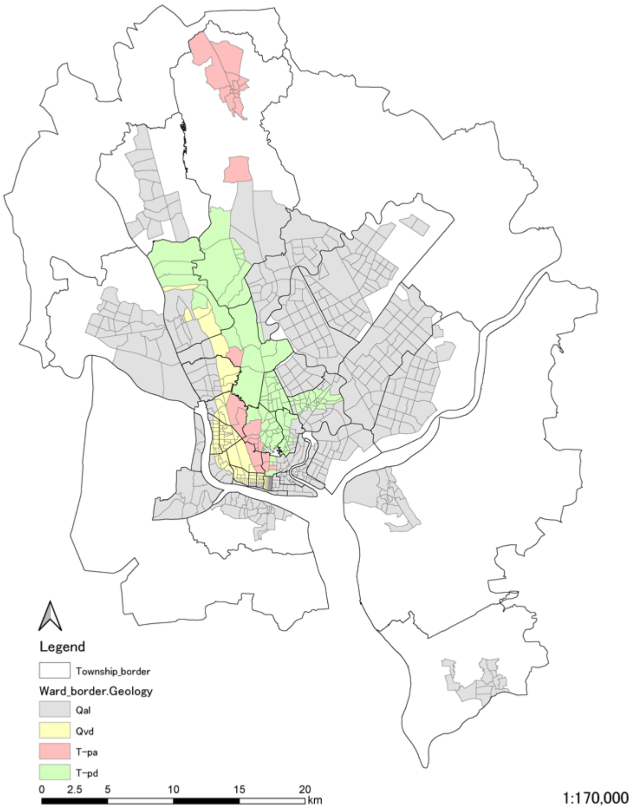
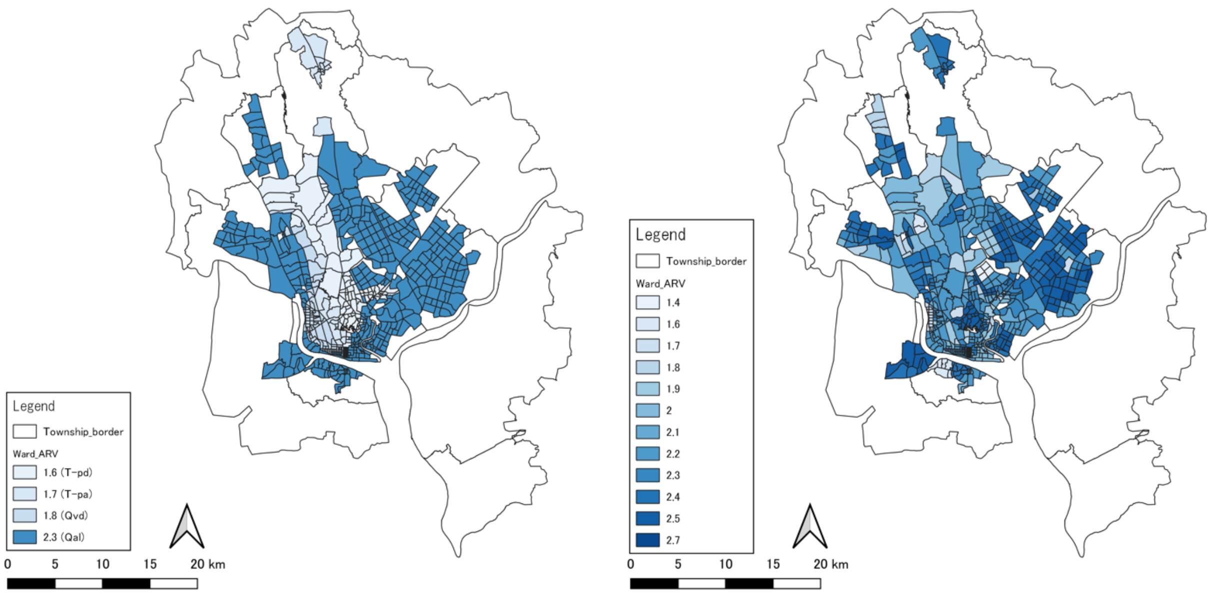


Fig. 3 – Ground condition classified by wards [5]



(a) Amplification (TMG [8]) according to ground conditions (H. H. Augn [11])

(b) Amplification based on field surveys

Fig. 4 – Comparison of site amplification distribution based on previous research and our field surveys

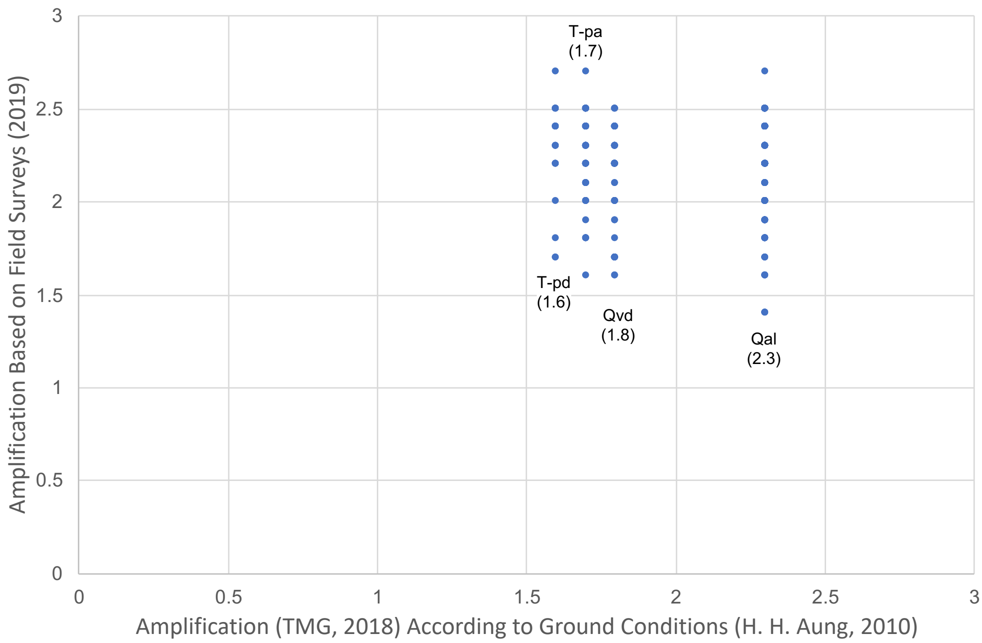


Fig. 5 – Comparison of site amplification based on previous research and our field surveys

3.4 Setting input ground motion

Input ground velocity is set as 30cm/s (kine) here based on the TMG method [7]. It is amplified according to the site amplification of each ward shown in Fig. 4 (b), responding to RQ.7 "What ground shaking is estimated?"

3.5 Vulnerability functions

It was necessary to construct vulnerability functions for each classified building type in order to RQ.6 "How can we develop vulnerability functions (fragility curves)?". In the previous study [5], the vulnerability functions for wooden buildings and RC buildings in Japan, which were constructed based on actual building damage dataset due to the 1995 Great Kobe Earthquake (Murao and Yamazaki [14]), were used.

As described in 3.2, there are mainly 9 structural types in the dataset. During the SATREPS project in Yangon, the authors had conducted field surveys and analyzed several building structural characteristics. Finally, the four types of recovery curves were obtained as shown in Figure 6.

The recovery curve of hut buildings was based on numerical and experimental approaches. Pull-over loading tests were conducted for the selected buildings in a slum district to assess the loading-displacement capacity of the buildings [13]. The recovery curve is used for (a) hut, (f) timber with CGI sheet roofing, and (g) timber buildings in this study.

The fragility curves of wood and brick-nogging buildings were developed by Prof. Koshihara based on building surveys and a numerical method. The fragility curve of wood is used for (b) wood buildings, and the curves of brick-nogging is applied for (c) brick-nogging buildings. The parameters for each curve are shown in Table 2.

In our SATREPS Project in Myanmar, Gadagamma [15] developed fragility functions for the existing RC buildings in Yangon using push over analysis, but it was based on the numerical analysis and did not adopt actual situation. Then, Hara et al. [16] revised those fragility functions based on material testing and field surveys at construction site in Yangon. Their fragility functions were developed for 2 and 7 story buildings in terms of rebar corrosion conditions. The fragility curve for 7 story buildings without rebar corrosion condition is adopted in this study, because most RC buildings in Yangon are mid/high rise buildings. Also, damage level of the fragility curves developed by Hara et al. were classified into four categories: slight, moderate, extensive, and complete. The complete condition is used here. The fragility curve is used for (d) RC with steel, (e) steel, and (h) RC buildings.

Remaining roadside shops, which are often located along the street, or in the market or slum districts, are anticipated to be easily collapsed by earthquakes. Therefore, it is assumed that all buildings of this category are damaged by the input earthquake motion in this study.

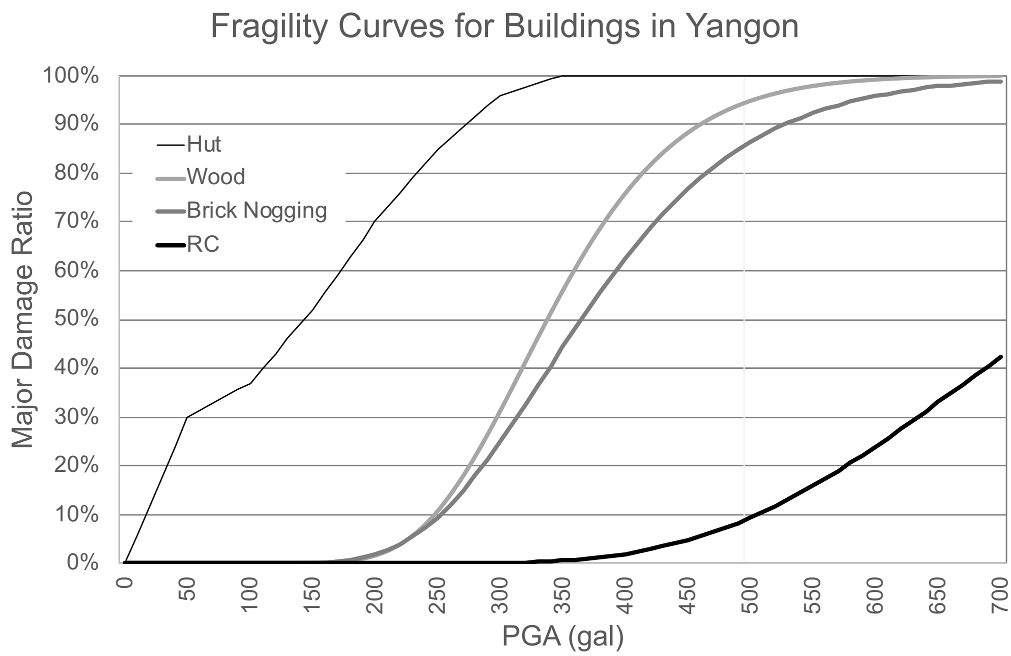


Fig. 6 – Fragility curves for buildings in Yangon [13]

Table 2 – Parameters of the fragility curves of wood, and brick-nogging buildings

	λ	ζ
Wood	5.82	0.24
Brick-nogging	5.90	0.29

3.6 Building collapse risk evaluation

Finally, the number of buildings damaged by the set ground acceleration per 10,000 m^2 for 567 wards, which is defined as "Building Collapse Risk Value," were calculated respectively. As a result, the maximum value became 78.90 in 12th Ward in Yankin Township and the minimum value became 0.00. Table 3 shows the ten worst vulnerable wards in terms of building collapse risk value. Four wards out of the ten are located in Dawpon Township.

While the building collapse risk evaluation in this study is recognized as Ver. 3.0, the authors calculated the building collapse risk value, as Ver. 2.1, for the objective wards in Yangon based on available datasets in the previous research [5]. The comparison of building collapse risk value between Ver. 2.1 and Ver. 3.0 is shown in Fig.7. Although it indicates high correlation coefficient by 0.70, building collapse risk value of Ver. 3.0 is about three times higher than of Ver. 2.1 in the wards. There seem two reasons of this result: (1) The amplification used in this study, as a result of field surveys, became higher than the previous one; (2) The actual building vulnerability in Yangon is higher than that used in the previous study [5] based on Japanese case [14].

The building collapse risk is classified into five categories from rank 1 as the lowest to rank 5 as the highest based on the standard normal distribution, allocated shown in Fig. 8. By the above procedure, building collapse risk map (Ver. 3.0), namely urban vulnerability map in terms of building collapse risk, was made as shown in Fig. 9(b). The previous map (Ver. 2.1) is also shown in Fig. 9(b).

Table 4 shows difference of the number of wards in building collapse risk ranking between this study and previous study [5], as well as ratio in whole. Totally, 412 wards (72.3%) were in the same ranking both in the previous and this study. It means that we could evaluate building collapse risk in Yangon with 72.3% accuracy based on temporal datasets even if we don't have enough information on building vulnerability functions and site amplification.

Table 3 – the ten worst vulnerable wards in terms of building collapse risk value

Place	Ward	Township	Total #Buildings	Total #Collapsed Buildings	Area ($10{,}000\ m^2$)	Building Collapse Risk Value
1	#12	Yankin	1,766	1,679	21.3	78.9
2	Bo Tun Zan	Dawpon	1,671	1,185	19.2	61.8
3	Yamonnar #1	Dawpon	812	721	11.8	60.9
4	Kannar (Middle)	Insein	686	291	5.4	53.7
5	Zay Galay	Kyimyintdai	314	197	3.7	52.7
6	Yamonnar #2	Dawpon	1,298	801	15.9	50.3
7	Kyi Zu	Dawpon	914	777	15.8	49.1
8	Manpyae #3	Tharkayta	1,949	1717	35.5	48.3
9	Nga Htet Gyee (South)	Bahan	547	472	9.9	47.5
10	Bayintnaung	Dala	875	798	16.9	47.2

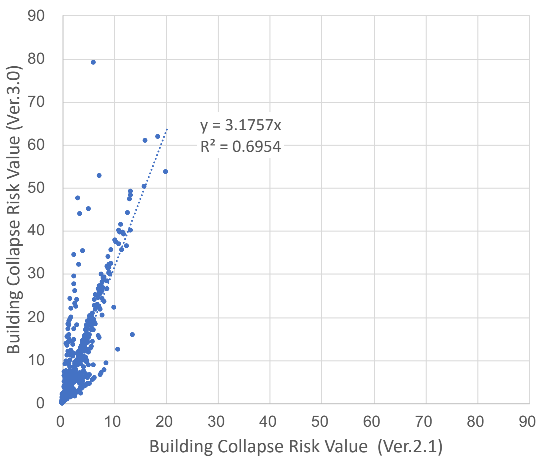


Fig. 7 – Comparison between building collapse risk value calculated by previous (Ver. 2.1) [5] and this study (Ver. 3.0)

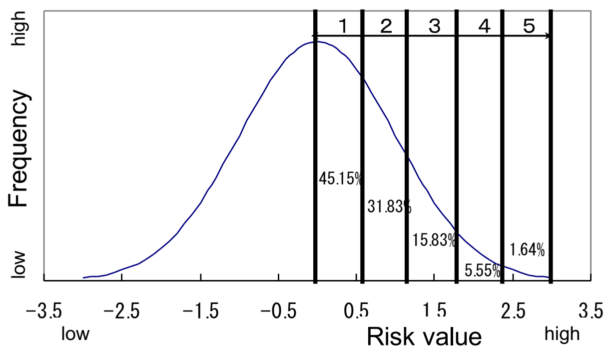
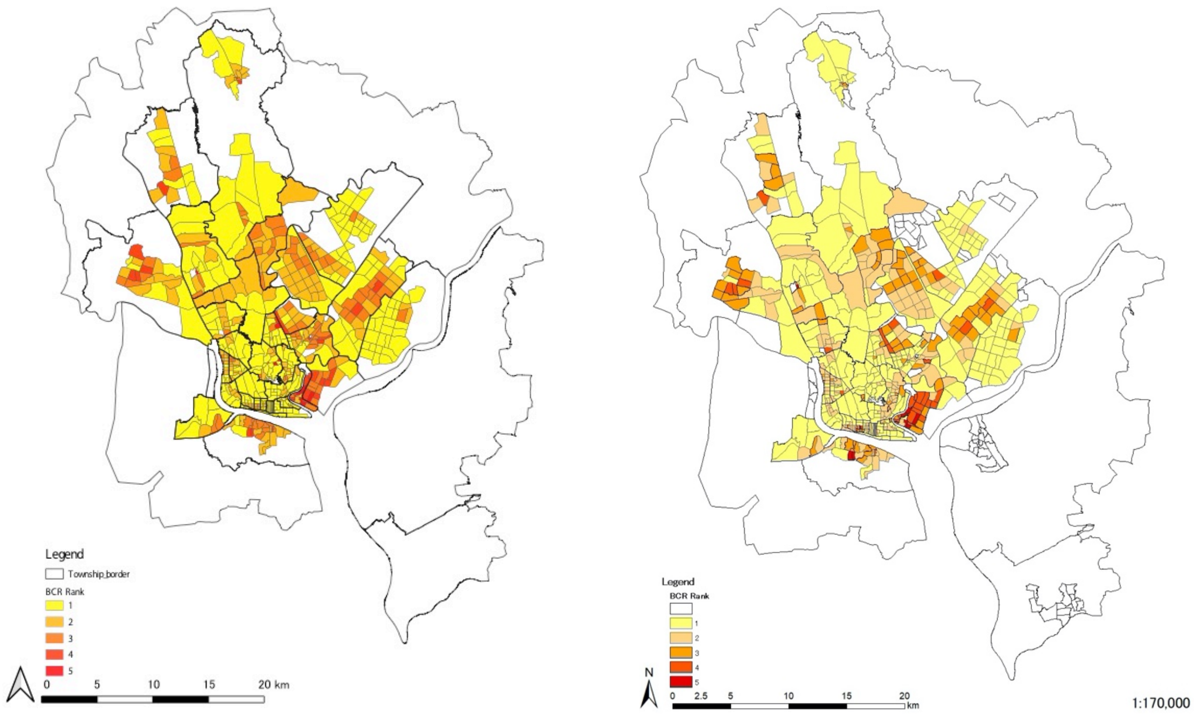


Fig. 8 – Ratio of risk rank allocation



(a) Ver 3.0 (this study) (b) Ver. 2.1 (tentative) [5]

Fig. 9 – Building collapse risk map of Yangon

Table 4 – Difference of building collapse risk ranking of the wards between this study and previous study [5]

		Ver.2.1 [5]					
		Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Total
Ver.3.0	Rank 1	213 (37.6%)	42 (7.4%)	1 (0.2%)	0	0	256 (45.1%)
	Rank 2	36 (6.3%)	114 (20.1%)	28 (4.9%)	3 (0.5%)	0	181 (31.8%)
	Rank 3	7 (1.2%)	19 (3.4%)	57 (10.1%)	6 (1.1%)	1 (0.2%)	90 (15.8%)
	Rank 4	0	5 (0.9%)	2 (0.4%)	22 (3.9%)	2 (0.4%)	31 (5.6%)
	Rank 5	0	1 (0.2%)	2 (0.4%)	0	6 (1.1%)	9 (1.6%)
	Total	256 (45.1%)	181 (31.8%)	90 (15.8%)	31 (5.6%)	9 (1.6%)	567 (100%)

4. Conclusion

Assessment of urban vulnerability is one of the important factors for urban development, especially for the cities which are rapidly urbanized such as Yangon, Myanmar. However, there are several problems to set it forward. The authors identified 7 research questions for building collapse risk evaluation of Yangon City.

Yangon City has not catalogued enough data for the regional assessment. Then, we tried to evaluate its building collapse risk with existing ground condition data which was published in 1934, and vulnerability functions for Japanese buildings developed by the actual building damage dataset due to the 1995 Great Kobe Earthquake [5]. As the final period of the project, we had obtained site amplification and building vulnerability functions based on field surveys in Yangon, pull-over loading tests of hut buildings, and numerical method.

This paper reports a procedure to assess urban vulnerability and evaluate building collapse risk of Yangon. The results are clarified as follows:

(1) The maximum building collapse risk value became 78.90 in 12th Ward in Yankin Township and the minimum value became 0.00. Four wards out of the ten worst wards are located in Dawpon Township.

(2) Although the comparison of building collapse risk value in our previous research and this study indicates high correlation coefficient by 0.70, building collapse risk value of this study is about three times higher than the previous version in the wards. There seem two reasons of this result: (i) The amplification used in this study, as a result of field surveys, became higher than the previous one; (ii) The actual building vulnerability in Yangon is higher than that used in the previous study based on Japanese case.

(3) Building collapse risk map (Ver. 3.0), namely urban vulnerability map in terms of building collapse risk, was made.

(4) Totally, 412 wards (72.3%) were in the same ranking both in the previous and this study. It means that we could evaluate building collapse risk in Yangon with 72.3% accuracy based on temporal datasets even if we don't have enough information on building vulnerability functions and site amplification.

Acknowledgements

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