

# Seismic Performance Evaluation of Existing Reinforced Concrete Buildings in Yangon

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## ABSTRACT

Yangon is the most populated commercial city in Myanmar. It is located just about 50km from Sagging Fault, the major earthquake fault of Myanmar, at which the ground excitation is more frequent this year. Moreover, most of the existing buildings in Yangon are old and less performance to seismic shaking. According to census data record, R.C type residential buildings are the most popular types in Yangon. Thus, in order to mitigate the risk of lives and properties under upcoming earthquake, the disaster mitigation plan becomes the major issue to get awareness of the public. For this purpose, this study is aimed to analyze the three existing R.C buildings under different levels earthquakes in three townships (Tarmway, Pazundaung and Kyaukdadar) in which the population density is higher and the soil condition is worse than other townships. The selected buildings have three heights (3; 6; and 8-stories). The material properties of these existing buildings are obtained by certain tests on sites. The soil condition of the existing townships is determined based on the bore logs test data of soil investigation reports. The performance of the buildings is then assessed with the ATC 40 and FEMA 356 building acceptance criteria. From pushover analysis, the capacity curves for each building in two directions of the earthquake are obtained. The modeling and analysis is done by ETABS 9 software. According to fragility analysis, this study results that these existing R.C type buildings can suffer moderate damage under moderate level and severe damage under severe level earthquake.

**Key Words:** R.C Buildings, pushover analysis, fragility analysis.

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## 1. INTRODUCTION

Myanmar, lying in the Alpide earthquake belt, is quite earthquake – prone. There had been at least 16 major earthquakes (M 7.0 – 7.9) and a great earthquake (M 8.0, 1912) in the past 175 years, some of which were quite destructive [1]. Besides, over the past decades, urbanization in Myanmar has been rapidly increasing. In Yangon, urbanization took place minimal consideration of building codes, sound construction, and urban planning practices. As a result, Yangon in the proximity of active seismic sources is at risk of experiencing major earthquake events.

In this study, the major type of buildings chosen for the study is reinforced concrete buildings which are the most popular type of buildings in Yangon. Most of the residential and commercial buildings in Yangon are R.C buildings which are heavy and the most dangerous among other types of structure if the strong earthquake happens

## 2. DESCRIPTION AND SELECTION OF STUDY AREA

Yangon is the most populated commercial city in Myanmar. Among 46 Townships of Yangon, Tarmway Township, Pazundaung Township and Kyaukdadar Township are selected for this study.

According to census report of Yangon (2004), the major housing units are residential apartments and the R.C type structures are the most popular among these buildings as in Table 1, 2 and 3. [2]. Thus, the study is aimed to the R.C type buildings which are almost in common type in Yangon.

Table-1 Type of Housing Units

	Total	Apartment/Condominium	Percentage of Total
Tarmway	35360	29261	83%
Pazundaung	10306	8460	82%
Kyaukdadar	6120	5913	97%

Table-2 Main Construction Material for the External Walls

	Total	Tile/Brick/ Concrete	Percentage of Total
Tarmway	35360	32296	91%
Pazundaung	10306	9566	93%
Kyaukdadar	6120	5997	98%

Table-3 Main Construction Material for the Floors

	Total	Tile/Brick/Concrete	Percentage of Total
Tarmway	35360	30246	86%
Pazundaung	10306	8217	80%
Kyaukdadar	6120	5682	93%

### 3. METHODOLOGY

The basic information to assess the seismic performance of the R.C type building is more detailed classified into two types of data: earthquake hazard data and building material data. The former includes: earthquake environment basic data – geological structure, earthquake zonation map, earthquake occurrence probability, historical earthquake information, and so on. The latter contains structural pattern and element, age, condition, materials, usage, site soil type, etc. To assess the seismic performance of the building to get the building damage assessment has to make the following steps.

#### 3.1 Earthquake Levels for Performance Check

The three earthquake levels: maximum operated earthquake (MOE), design basis earthquake (DBE), and maximum considered earthquake (MCE) are defined with 50%, 10% and 2% probabilities of being exceeded in a 50-year period.

#### 3.2 Determination of Site Soil Condition

The average standard penetration resistance,  $N$  is determined by the following formula,

$$\bar{N} = \frac{d_s}{\sum \frac{d_i}{N_i}}$$

where  $d_s$  is the total thickness of soil profile,  $d_i$  is the thickness of soil layer  $i$  and  $N_i$  is the standard penetration resistance of layer  $i$ .

From the above formula, the soil classification is made for the three townships. From the soil investigation data from Yangon City Development Committee(Y.C.D.C), the following soil data can be calculated.

Table-4 Soil Type Calculation Results

Tarmway Township			
	Street	Average N Value	Soil Type
1	156 <sup>th</sup> Street	5.67	S <sub>E</sub>
2	Bayatheikdi Street	10.58	S <sub>E</sub>

3	Thiri Street	14.52	S <sub>E</sub>
4	Ah Yoe Gone Street	10	S <sub>E</sub>
5	Pone nar Kone Street	9	S <sub>E</sub>
6	Myo Thit (2) Street	7.78	S <sub>E</sub>
<b>Pazundaung Township</b>			
1	50 <sup>th</sup> Street	6.43	S <sub>E</sub>
2	Kaung Yan Street	8.56	S <sub>E</sub>
3	Lower Pazundaung Road	8.5	S <sub>E</sub>
4	51 <sup>st</sup> Street	7.2	S <sub>E</sub>
5	Yay Kyaw Street	8.2	S <sub>E</sub>
6	Thar Yar Kone Street	11	S <sub>E</sub>
<b>Kyaukdadar Township</b>			
1	Pansodan Street	18.6	S <sub>D</sub>
2	40 <sup>th</sup> Street	16.5	S <sub>D</sub>
3	Anaw Yahtar Road(Middle)	21.8	S <sub>D</sub>
4	Anaw Yahtar Road(East)	18.5	S <sub>D</sub>
5	39 <sup>th</sup> Street	22.6	S <sub>D</sub>
6	Merchant Road	20.3	S <sub>D</sub>

From the soil calculation, soil profile type for Kyaukdadar Township is regarded as S<sub>D</sub> and for Tarmway and Pazundaung Townships as S<sub>E</sub>.

### 3.3 Determination of Material Strengths

The material data is important in building analysis. Thus, the compressive strength of the existing buildings is measured by using rebound hammer. Testing procedure is followed to ASTM C805.

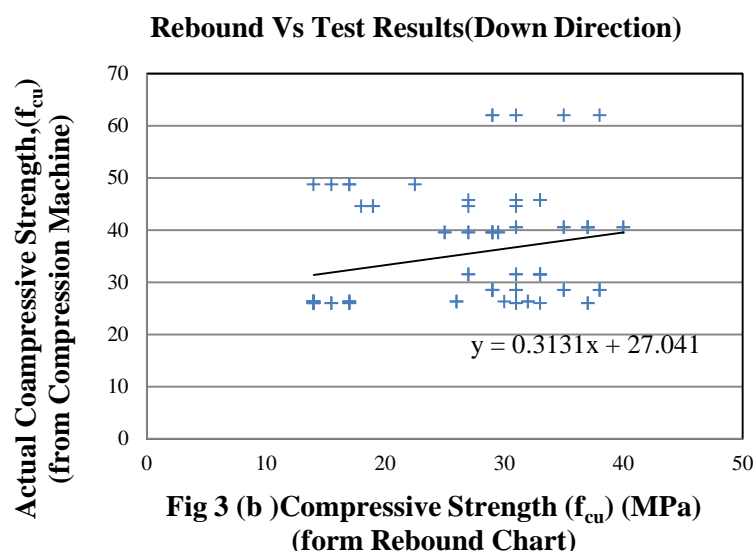
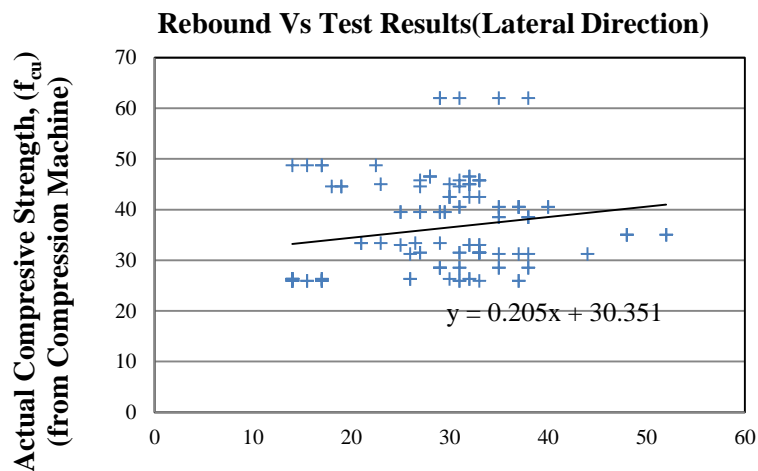
The calibration of the rebound hammer is done by compressive machine test data as shown in Fig.1 The results obtained from the rebound value of the tube mould and the actual compressive strength obtained from the compressive machine is graphed to get the correlated equation as shown in Fig 2.



Fig. 1 (a) Compressive machine and Data recording



Figure 2. (b) Test by Rebound Hammer on Existing Members



**Fig. 2 Calibrated Graphs for Rebound Hammer (a) Lateral Direction (b) Down Direction**

The concrete condition of the existing R.C buildings are then tested using rebound hammer. From the test results, the following data can be obtained as in Table 5.

**Table-5 Test Result of Compressive Strength of Concrete**

Building Age	Number of Story	$f_{cu(avg)}$ (MPa)
More than 20 years	3,4	25.5
10 years to 15 years	3,6,8	28.5
Less than 10 years	3,5,8	33

The concrete compressive strength of the existing buildings is then taken as 25Mpa, average value for all buildings in modelling and analysis.

On the other hand, the tensile strength of reinforcing steel is taken 40000 psi as per as-built design drawings from Y.C.D.C. The location and number of rebars are checked on site by rebar locator (profoscope).

### 3.4 Structural Analysis

The structural analysis includes the following steps.

- (i) Linear static Analysis
- (ii) Response Spectrum Analysis
- (iii) Non-linear Static Analysis

### 3.5 Performance Assessment

The seismic performance of buildings is measured by the state of damage under a certain level of seismic hazard. The state of damage is quantified by the drift of the roof and the displacement of the structural elements. Initially, gravity push is carried out using force control method. It is followed by lateral push with displacement control using Etabs 9.

For carrying out displacement based pushover analysis, target displacement need to be defined. Pushover analysis gives an insight into the maximum base shear that the structure is capable of resisting.

A performance level describes a limiting damage condition which may be considered satisfactory for a given building with specific ground motion. Table-6 describes the performance levels for the structure.

**Table-6 Performance Levels Description(FEMA 356)**

Type	Structural Performance Level		
	Collapse Prevention (CP)	Life Safety (LS)	Immediate Occupancy(IO)
Drift	4% transient or permanent	2% transient; 1% permanent	1% transient; negligible permanent

## 4. CASE STUDY BUILDINGS

Three R.C Buildings are selected for performance check as case study. Table-7 describes the input information of the building modeling.

**Table-7 Case Study Building Information**

	<b>Building A</b>	<b>Building B</b>	<b>Building C</b>
<b>Township</b>	Kyaukdadar	Pazundaung	Tarmway
<b>Dimension</b>	10.5' x 45'	25'x50'	28'x52.5'
<b>Number of Story</b>	3	6	8
<b>Total Height</b>	45'	62'	100'
<b>Usage</b>	Residential	Residential	Residential
<b>Slab Thickness</b>	4"	4"	4"
<b>Concrete, f'c(psi)</b>	3000	3000	3000
<b>Reinforcing Steel, fy(psi)</b>	40000	40000	40000
<b>Soil Type</b>	S <sub>D</sub>	S <sub>E</sub>	S <sub>E</sub>

## 5. RESULTS AND DISCUSSION

### 5.1. Modeling

The structures were analysed using Etabs 9 computer code. The superstructure was modelled by considering fixed support at the base. The reinforced concrete floor has substantial stiffness and resistance to take over the stresses produced by the lateral forces, and due to the regularity and homogeneity of the structure, it can be considered non-deformable in its plan. The beam and column elements are modelled as nonlinear frame elements with lumped plasticity by defining plastic hinges at both ends of beams and columns.

### 5.2. Performance of the buildings

Results of the Push-Over analysis are presented in Fig 3, 4 and 5. (push-over curves, in each of the 2 main directions). The performance point at the intersection of the capacity spectrum with the single demand spectrum for different levels of shaking (MOE, DBE and MCE) has been obtained.

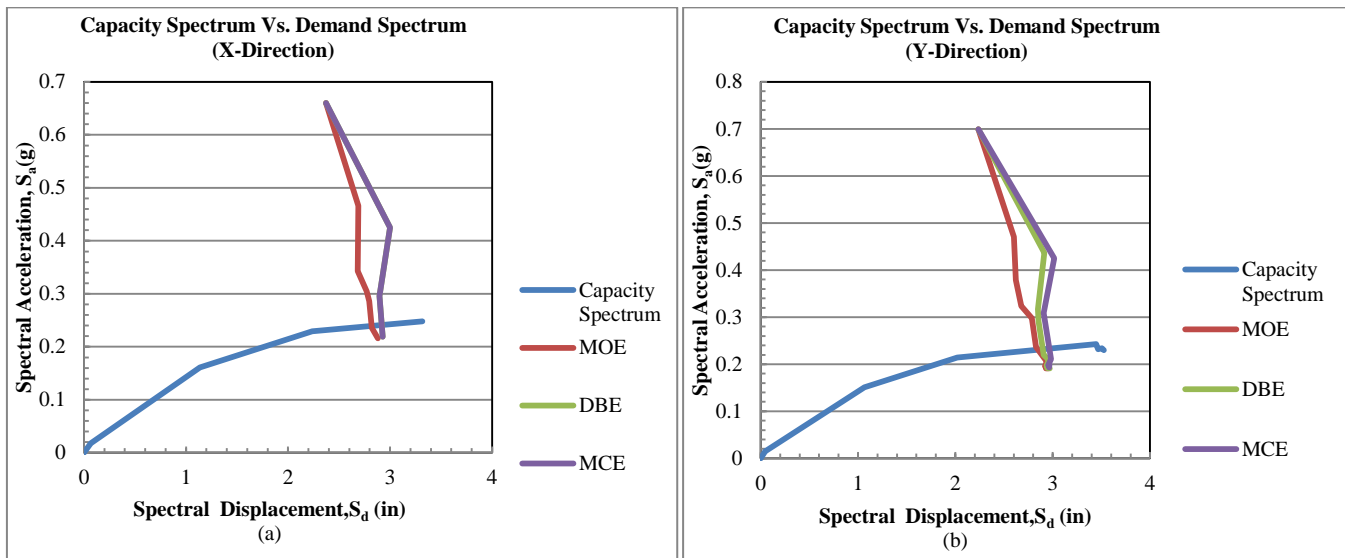


Fig. 3 Pushover Curve for 3 story R.C Building (a) X-direction (b) Y-direction

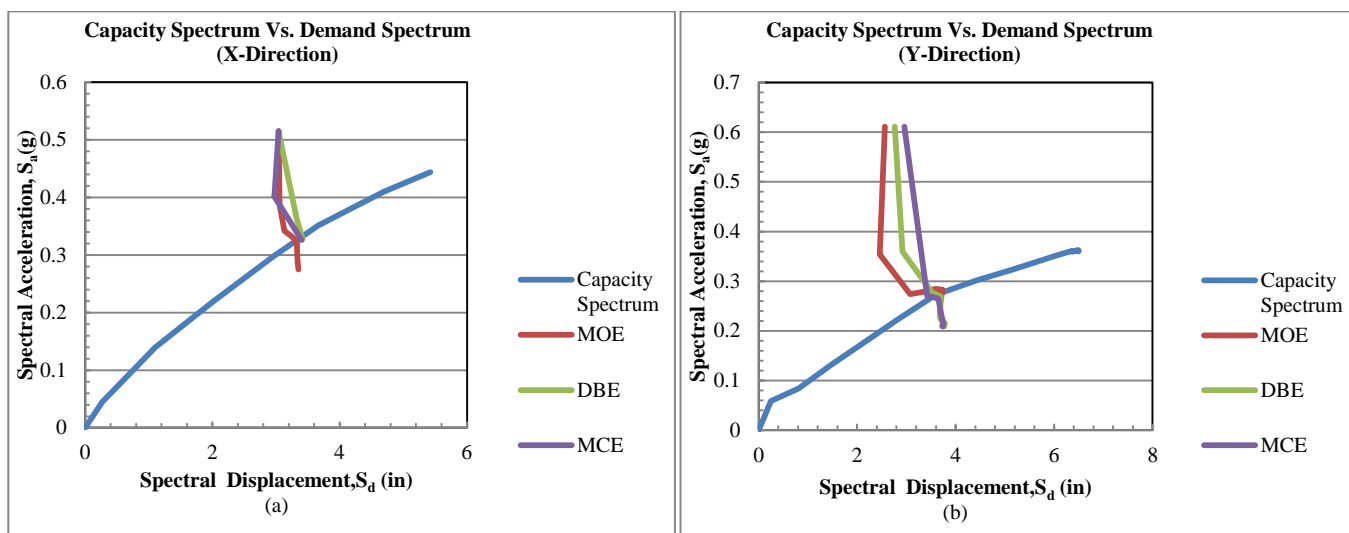


Fig. 4 Pushover Curve for 6 story R.C Building (a) X-direction (b) Y-direction

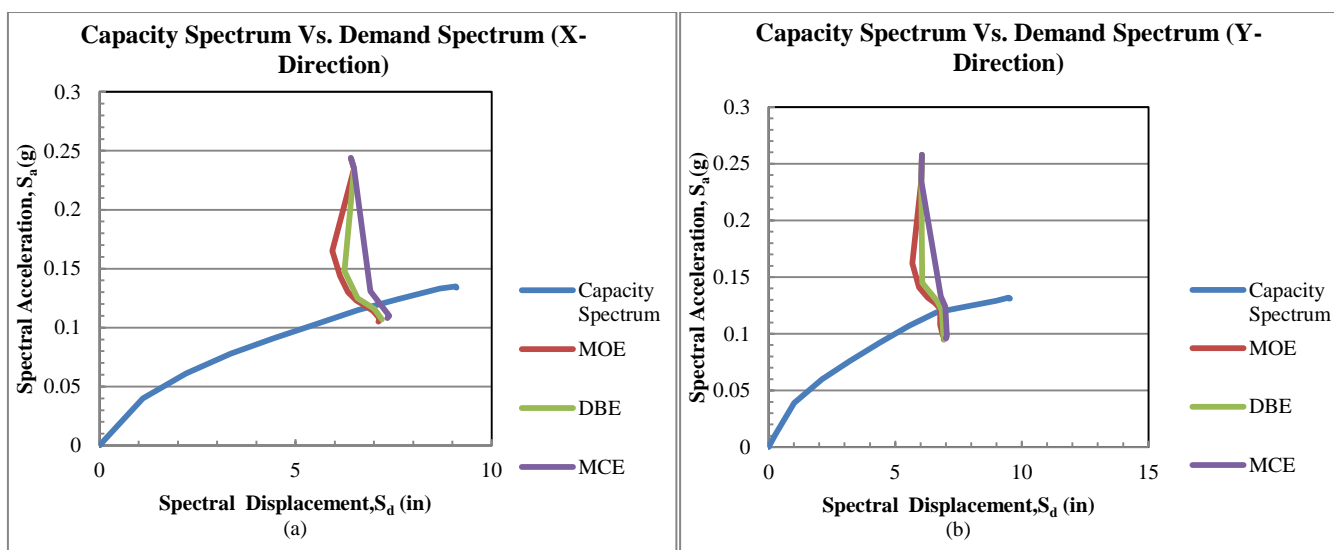
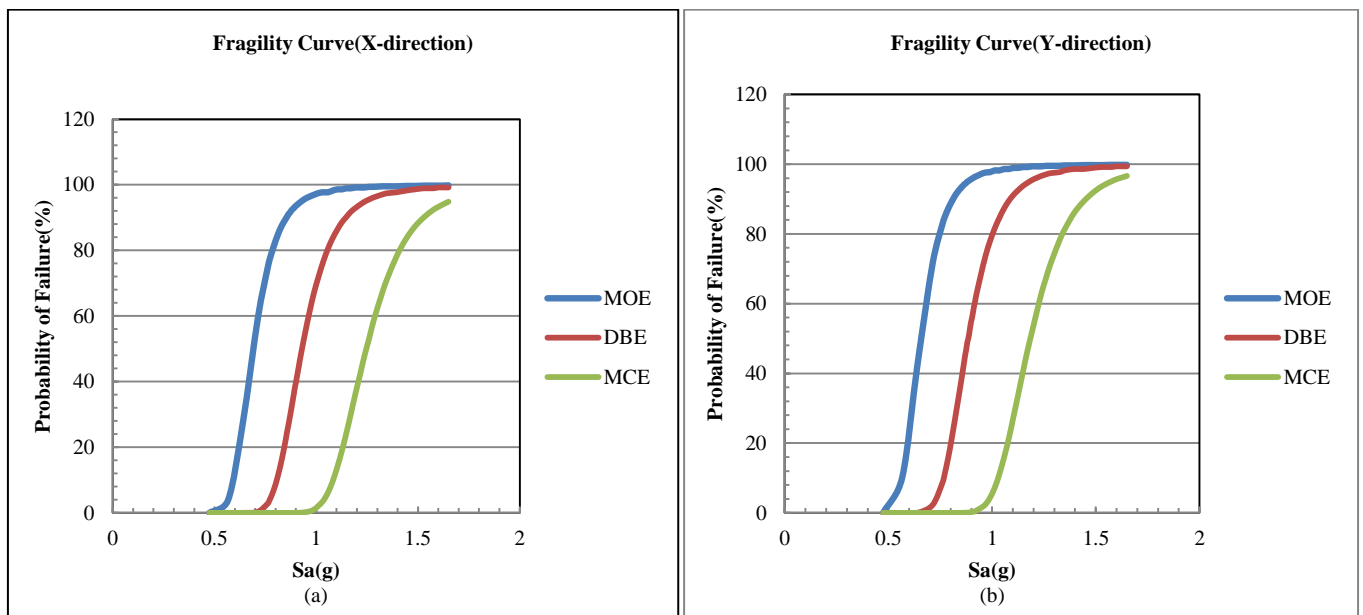


Fig. 5 Pushover Curve for 8 story R.C Building (a) X-direction (b) Y-direction

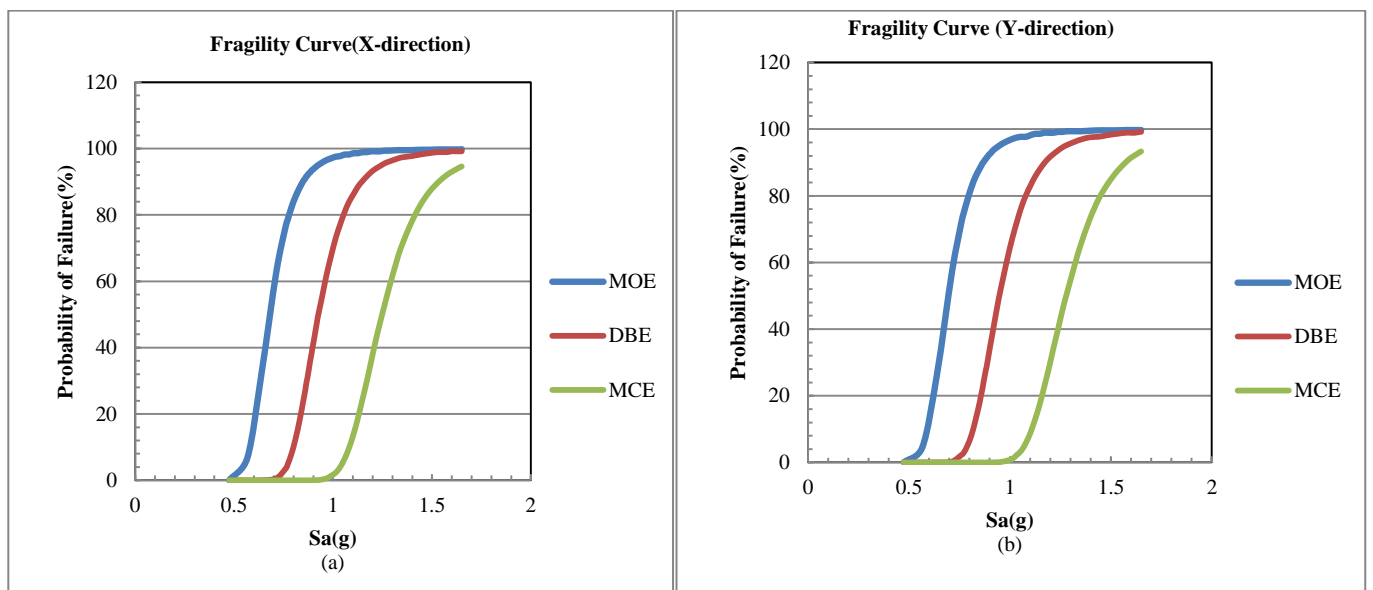
### 5.3 Fragility Curve

The fragility analysis is done base on the spectral displacement of analysis of each of the buildings. The fragility curve is drawn for each level of earthquake and the probability of failure is obtained based on this fragility curve as in Fig 6, 7 and 8. From these fragility curves,



**Fig. 6 Fragility Curve for 3 story R.C Building (a) X-direction (b) Y-direction**

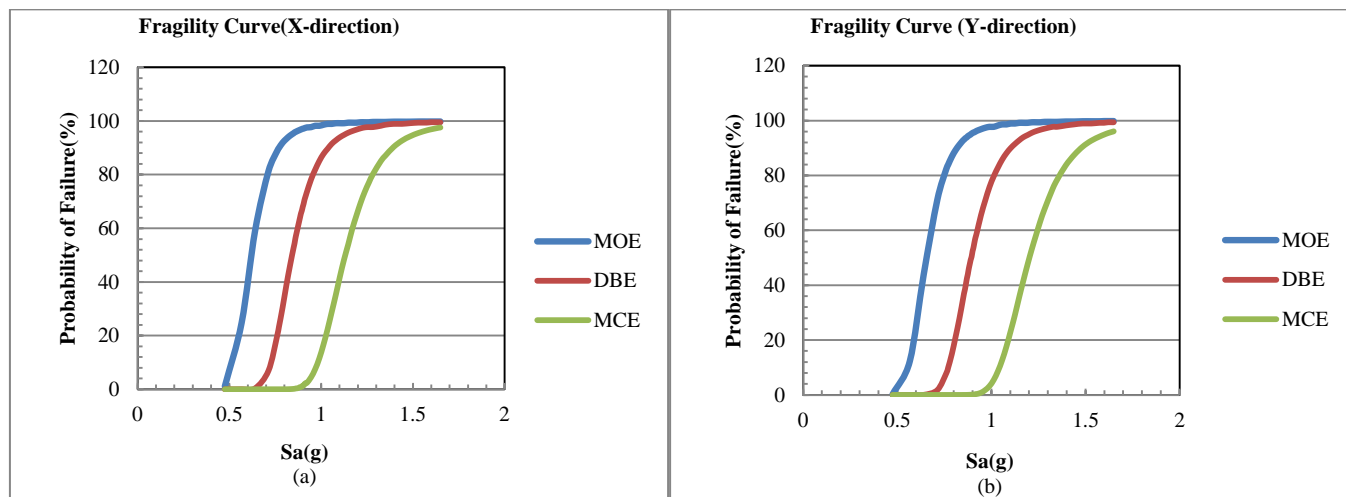
According to the fragility curve of 3 story R.C Building, it is in the 59.6% immediate occupancy damage state due to the spectral acceleration of 0.743 g excitation for MOE. The building is in the 22.36% failure of life safety state due to 0.85g for DBE and 93.4% will collapse for MCE with 1.65g excitation.



**Fig. 7 Fragility Curve for 6 story R.C Building (a) X-direction (b) Y-direction**

According to the fragility curve of 6 story R.C Building, it is in the 33.56% immediate occupancy damage state due to the spectral acceleration of 0.645 g excitation for MOE. The building is in the 24.21% failure of life safety state due to 0.81g for DBE and 92.2% will collapse for MCE with 1.65g excitation.





**Fig. 8 Fragility Curve for 8 story R.C Building (a) X-direction (b) Y-direction**

According to the fragility curve of 8.5 story R.C Building, it is in the 48.6% immediate occupancy damage state due to the spectral acceleration of 0.74 g excitation for MOE. The building is in the 26.36% failure of life safety state due to 0.85 g for DBE and 95.45% will collapse for MCE with 1.65g excitation.

#### 4. CONCLUSION

From this study, the existing reinforced concrete buildings cannot withstand under severe earthquake and thus retrofit and strengthening is required for severe earthquake levels.

For DBE level earthquake, 3 story building can be damaged about one fourth of the total building members and about almost all can be damaged under MCE level earthquake. The 6 story building can have about 25% damage for life safety level earthquake and more than 90% probability of failure under severe earthquake.

And also, the 8 story building has damages of more than a quarter of the total under moderate earthquake (DBE) and over 95% probability to be damaged under MCE earthquake. Therefore, it can be clearly seen that the existing R.C buildings in Yangon cannot withstand for severe level earthquake.

#### 5. RECOMMENDATIONS

The soil data in Yangon is much different in various townships. Thus, the R.C buildings in other townships with different soil data should be considered for further study. Moreover, this study is aimed for R.C type buildings in Yangon. The other types of buildings such as wooden and masonry buildings are also long lives in some townships. The performance check of these building structures should also be studied.

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