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Seismic vulnerability assessment of Sta. Lucia high school in Pasig City Philippines using rapid visual assessment and fragility curves

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A B S T R A C T

The Philippines being part of the pacific ring of fire, faces huge threats of massive damage to infrastructures after extensive earthquakes. One of the most vulnerable infrastructures is public school buildings, which are considered significant structures since they have both emergency and educational function value to the society. Sta. Lucia High School in Pasig, located near the West Valley Fault, will be the focus of this paper. The main objectives of this research are to implement rapid visual assessment using Safer Communities through Safer Schools (SCOSSO) application and to generate the seismic fragility curve of the building based on the Capacity-Spectrum Method. The researchers conducted a rapid but thorough assessment of the BCE II building by following the guidelines of the SCOSSO application. The building had an estimated seismic vulnerability of 66%, thus needing further comprehensive assessment. For the generation of fragility curves, the structural plan of the building was modeled in SAP2000 and subjected to 20 ground motion data. The results from the capacity spectrum method were then used for the seismic fragility curves. The structure was found to attain its completely damaged state at a PGA of 0.352g or greater, with a probability exceedance of 10% which takes place at the weaker axis of the building in the north-south direction of the earthquake along the x-axis. The fragility curves have shown that the stronger the peak ground acceleration, the higher the chance of the building to collapse.

A R T I C L E I N F O

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INTRODUCTION

Large destructive earthquakes are seldom to occur, but it occurs without a caution (Paton et al., 2015). These earthquakes have resulted widespread loss of properties and life when close to inhabited districts (El-Betar, 2016). Thus, preparation for such disaster is significant. The destruction impact of individual hazards like earthquake has been witnessed and documented throughout the centuries (Martin et al., 2019). In relation to this, Gilani, Miyamoto and Nifuku in 2018 have noted that widespread damage to structures in developing nations has occurred in the recent earthquakes, and school buildings were particularly damaged and considered as structures with a worst performance in comparison to other infrastructures. The risks brought by an earthquake led to management of risk reduction plans, wherein one method that is used in earthquake risk mitigations is Seismic Vulnerability Assessments. It is done to find out how structurally sound a building is when there is a seismic activity involved (Baylon et al., 2018). Assessment of existing school buildings for seismic susceptibility is a critical step in preventing losses from future disasters, particularly earthquakes, and also improves community preparedness.

In the Philippines, one of the major fault lines is the Valley Fault System, consisting of two sections: the 10 km East Valley Fault and the 100 km West Valley Fault (Michael B. Baylon & Marcos, 2018). Presently, PHIVOLCS has a warning to Metro Manila about the occurrence of "The Big One", a 7.2 magnitude earthquake which is based on the West Valley Fault's length and is categorized as "Very Destructive" (news.abs-cbn.com). Due to this, different studies are conducted involving the assessment and evaluation of the seismic vulnerabilities of different structures. In this study, the researchers focused on Sta. Lucia High School, a public school located in Pasig City, Philippines, which is approximately 3.4 km from the West Valley Fault (M. B. Baylon et al., 2020).

This study aimed to perform a seismic vulnerability assessment of Sta. Lucia High School in Pasig City, Philippines using rapid visual assessment and fragility curves. Specifically, to model the As-Built Plan of the BCE II building of Sta. Lucia High School, to determine the compressive strength of the structural columns of BCE II building using Schmidt Rebound Hammer Test, to implement rapid visual assessment using Safer Communities through Safer Schools (SCOSSO) application, to determine the Pushover Curve, Capacity Curve and analyze the Response Spectra of the BCE II building using Capacity-Spectrum method, to construct the seismic fragility curve of the school building based on the result of the Capacity-Spectrum Method, and to generate recommendations for future researches about multi-hazard vulnerability assessment of other infrastructures (Alfonso et al., 2020).

Scope, Limitation, and Delimitation of the Study

The scope of this study includes the seismic vulnerability assessment of the BCE II Building of Sta. Lucia High School in Pasig City, Philippines. For the testing of the structural integrity of the building, the researchers used AutoCAD and SAP2000, a structural engineering software for modelling As-built plans and conducting earthquake simulations. For the modelling of the structure, the Takeda Model, which has fixed end supports, was used as basis for this research. Other software used is Microsoft Excel, which was used in analyzing the results from the tests done (Alam & Haque, 2020). The study is also limited to the ground motion data obtained from online research. The Ground Motion Data presented in Table 1 and Table 2 were obtained from Incorporated Research Institutions for Seismology (IRIS). Table 1 shows the ten highest earthquake magnitudes recorded every year in the Philippines from the year of 2009 to 2018. Likewise, Table 2, presents the ten highest recorded earthquake magnitudes which occurred in foreign countries located within the Pacific Ring of Fire from the years 2009 to 2018 (Liu et al., 2019).

Table 1: *Highest earthquake magnitudes in the Philippines from 2009-2018*

Location	Magnitude	Month	Day	Year
Mindanao, Philippines	6.6	10	04	2009
Mindanao, Philippines	7.7	07	23	2010
Negros, Philippines	6.5	07	11	2011
Philippine Islands Region	7.6	08	31	2012
Mindanao, Philippines	7.1	10	15	2013
Mindanao, Philippines	6.6	12	02	2014
Leyte, Philippines	6.1	07	03	2015
Mindanao, Philippines	6.3	09	23	2016
Mindanao, Philippines	6.9	04	28	2017
Mindanao, Philippines	7.0	12	29	2018

Table 2. *Highest earthquake magnitudes in the pacific ring of fire from 2009-2018*

Location	Magnitude	Month	Day	Year
Samoa Islands Region	8.1	09	29	2009
Near Coast of Central Chile	8.8	02	27	2010
Near East Coast of Honshu, Japan	9.1	03	11	2011
Off W Coast of Northern Sumatra	8.6	04	11	2012
Sea of Okhotsk	8.3	05	24	2013
Near Coast of Northern Chile	8.1	04	01	2014
Near Coast of Northern Chile	8.3	09	16	2015
New Ireland Region, P.N.G.	7.9	12	17	2016
Near Coast of Chiapas, Mexico	8.1	09	08	2017
Fiji Islands Region	8.2	08	19	2018

The methodology applied in generating the fragility curves in this research is limited to the Capacity Spectrum Method. The data which will be obtained from the Schmidt Rebound Hammer Test will be used for the structural modelling in SAP2000. For the Schmidt Rebound Hammer Test, the critical structural columns were chosen based on their tributary areas. Moreover, one column was chosen as representative column for corner columns, interior columns, exterior columns, and stair columns. The Safer Communities through Safer Schools (SCOSSO) application will be used to determine the seismic vulnerability index of the structure. This application is a procedure used for Rapid Visual Assessment. For the mode of failure, only shear was considered (Alam & Haque, 2020). The other consequences of earthquakes aside from the possible damage to the structure will not be discussed in this study. Moreover, the tensile strength input for the modelling will be obtained from the general notes of the engineering plans. Also, the soil-structure interaction will not be considered. Lastly, this study will not include the probable cost of damage and the type of retrofitting which will be appropriate for the public-school building.

OBJECTIVES

This research aims to perform a seismic vulnerability assessment of Sta. Lucia High School in Pasig City, Philippines using rapid visual assessment and fragility curves. Specifically, to model the As-Built Plan of BCE II of Sta. Lucia High School, to determine the compressive strength of the structural columns of BCE II building using

Schmidt Rebound Hammer Test, to implement rapid visual assessment using Safer Communities through Safer Schools (SCOSSO) application, to determine the Pushover Curve, Capacity Curve and analyze the Response Spectra of Sta. Lucia High School using Capacity-Spectrum method, to construct the seismic fragility curve of the school building based on the result of the Capacity-Spectrum Method, and to generate recommendations for future researches about multi-hazard vulnerability assessment of other infrastructures.

METHODS

Research Design

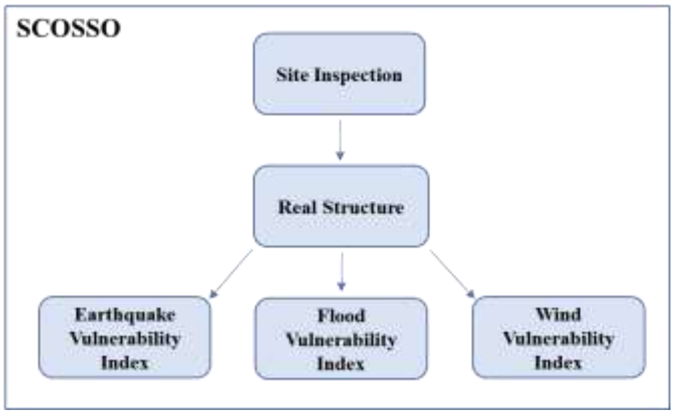

Figure: *Research design using rapid visual assessment*

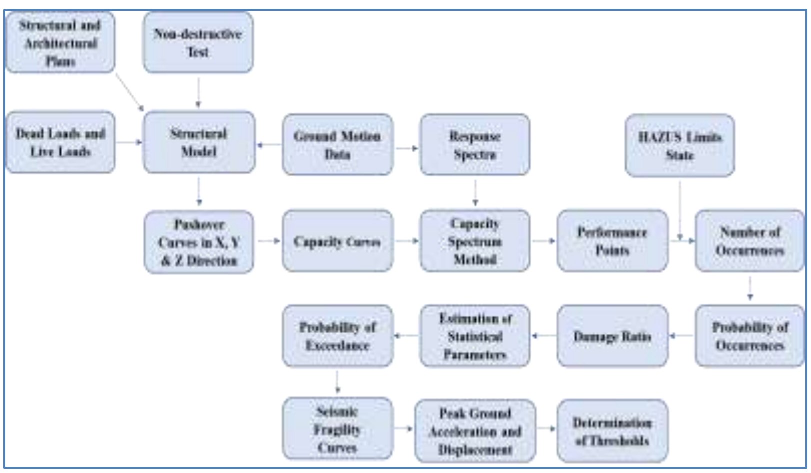

Figure 2: *Research design using fragility curves*

The researchers' aim was to create seismic fragility curves of the Sta. Lucia High School building by using Rapid Visual Assessment and Capacity Spectrum Method. The researchers acquired the structural plans of the Sta. Lucia High School building from Pasig City Hall. The structural plan obtained was presented using the SAP2000 application. The modeled structure was subjected to ground motion data, which was assessed after, by using capacity spectrum method. The values produced by these analyses have been used for the construction of seismic fragility curve as shown in Figure 2. The Rapid Visual Assessment shown in Figure 1 can be used by any personnel to identify, inventory, and screen buildings that are possibly seismically vulnerable. The RVA was done using an application called SCOSSO (Safer Communities through Safer Schools) that includes a method and several forms that help users to rapidly identify, inventory, and score buildings in terms of their risk of collapse if happened to hit by major earthquakes (Koliou et al., 2016). The SCOSSO Application gave the seismic vulnerability index of the structure, wherein if it exceeded 50%, the structure must be assessed for its seismic vulnerability. Otherwise, assessment would not be necessary.

Sampling Method

Extreme value distribution, **t**he researchers used the critical structural columns which were chosen based on their tributary areas. Moreover, one column was chosen as representative column for corner columns, interior columns, exterior columns, and stair columns. Ground motion data, the ground motion data used were from earthquakes within the Pacific Ring of Fire and that had happened in the Philippines to create a much more realistic scenario. This was bound by the principle of selective sampling.

Research Procedures

Rapid visual assessment, the researchers utilized the application called Safer School through Safer Communities (SCOSSO) Application and integrated the FEMA guidelines in performing the rapid visual assessment. The application assisted the researchers by increasing the efficiency, precision, and speed of the rapid visual survey. The researchers used the information from the school registry documents aside from the actual rapid visual assessment made. Rebound hammer test, was also utilized to determine the in-situ compressive strength of concrete to better model the behavior of structural members. SAP2000-Nonlinear Static Analysis (Pushover Analysis) was used to show the relationship between the force and displacement from the push-over curve by transforming it into Capacity Curves using FEMA ATC. Ground Motion Data was transformed into Response Spectra form using PRISM to show the relationship between the structural response period and the peak ground acceleration. Performance points is the graphical intersection of the Capacity Curves and Response Spectra approximates the response of the structure called performance points. By converting the base shears and roof displacements from a non-linear to equivalent spectral accelerations and displacements and superimposing an earthquake demand curve, the non-linear pushover became a capacity spectrum. The damage state thresholds defined with the agreement of the capacity spectrum is shown in the table below:

Table 3. *Damage state threshold (Vasavada & Patel, 2016)*

Damage States	Spectral Displacements
Slight	$0.7Dy$
Moderate	Dy
Extensive	$Dy + 0.25(Du - Dy)$
Collapse	Du

Where:

Ay = yield spectral acceleration
Au = ultimate spectral acceleration
Dy = yield spectral displacement
Du = ultimate spectral displacement

Damage State and Number of Occurrences

The damage indices were calculated and calibrated to their respective rank by using the computed value of damage state thresholds in Table 3. To obtain the number of occurrences of each damage state threshold, the computed values of damage state thresholds were used as written in Table 4.

Table 4. *Damage state and damage rank relationship (Abbasi & Moustafa, 2019)*

Damage State (DS)	Damage Rank (DR)	Definition
$0.00 < DS \leq 0.14$	D	No damage
$0.14 < DS \leq 0.40$	C	Slight Damage
$0.40 < DS \leq 0.60$	B	Moderate Damage
$0.60 < DS \leq 1.00$	A	Extensive Damage
$1.00 \leq DS$	As	Complete Damage

Damage Ratio

The damage ratio is the number of occurrences of each damage rank (no, slight, moderate, extensive, and complete) divided by the total number of records. It was plotted against the natural logarithm (ln) of (PGA) to determine the mean and standard deviation that were used to construct the fragility curves.

Statistical Treatment

The probability of exceedance values was computed using the statistical formulas used for ungrouped data. The probability distribution parameters in assessing the safety, reliability, and risk and Life-Cycle performance of structures are λ and ξ based from Ang & Tang in Baylon in 2018. To compute for the mean (λ), it is given by Equation 1 and the formula for computing the standard deviation (ξ) is given by Equation 2.

Mean

$$\lambda = \frac{\Sigma x}{N} \quad (1)$$

Where:

λ = mean ground motion data
x = individual ground motion data obtained
N = the sample size of ground motion data obtained

Standard Deviation

$$\xi = \sqrt{\frac{\Sigma(x-\lambda)^2}{N-1}} \quad (2)$$

Where:

λ = mean ground motion data obtained from Equation 1
x = individual ground motion data obtained
N = the sample size of ground motion data obtained

Seismic Fragility Curves

To develop the fragility curves, parameters such as the mean and standard deviation were needed. These parameters were obtained by plotting the value of damage ratio against the natural logarithm of PGA on a lognormal probability paper. Upon obtaining the values of the standard deviation and mean, Equation 3 was used to compute for the probability of exceedance (PoE) of the damage equal or higher than the damage rank.

Probability of Exceedance

$$PoE = \Phi\left[\frac{\{\ln(X) - \lambda\}}{\xi}\right] \quad (3)$$

Where:

PoE – Probability of Exceedance
Φ – Standard Normal Distribution
X – Peak Ground Acceleration
λ – Mean
ξ – Standard Deviation

Determination of Thresholds

The researchers selected three (3) out of the 20 ground motion data used to determine the thresholds of the BCE II Building. The maximum and minimum structural response peak ground acceleration were then acquired when the structure was subjected to the scaled GMD based on the peak ground acceleration of moderate damage rank of fragility curves with 10% Probability of Exceedance. The moderate damage rank was used because these curves were used for retrofitting assessments (Hamburger, 2019).

RESULTS AND DISCUSSION

As-Built Plan Modelling

This study utilized SAP2000 to model the As-Built plan of BCE II Building of Sta. Lucia High School. The structural modelling off the building encompasses all the important structural details of the building and is limited only in the concrete works. Figure 3 represents the BCE II Building's structural model.

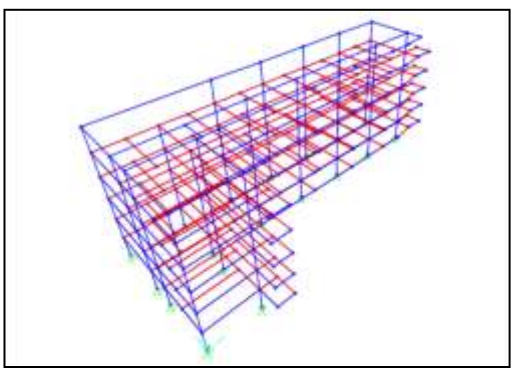

Figure 3. *Structural model of BCE II building of Sta. Lucia high school*

Compressive Strength of Structural Columns using Schmidt Rebound Hammer Test

In this research, the compressive strengths of the most critical columns of BCE II Building of Sta. Lucia High School were determined using Rebound Hammer Test. Each rebound number obtained was correlated to its compressive strength using the graph adapted from the manual of Proceq's Schmidt Rebound Hammer. The results in Table 5 shows inconsistency with the given maximum compressive strength of Sta. Lucia High School which is 28 MPa. Several results have shown values near to 28 MPa, but most values depict a great discrepancy with the compressive strength used. This can be explained using the study of Co (2019) which revealed that rebound hammer prediction of compressive strength was accurate between 48 to 58 MPa with 15.32% error. On the other hand, the rebound hammer is inaccurate beyond that range. In addition, Sanchez and Taranza (2014) observed that the results coming from the rebound hammer is lower in comparison to the actual compressive strength.

Table 5. *Rebound hammer test results*

Column	1st Floor	2nd Floor	3rd Floor	4th Floor	5th Floor	6th Floor
A4	35.85	22.98	29.88	34.19	18.96	24.13
A7	12.35	15.17	21.55	34.47	22.98	35.85
B1	34.47	35.85	28.15	12.41	28.15	29.88
B5	25.57	28.15	21.55	33.09	28.15	30.34
C1a	29.88	22.98	22.98	38.61	31.6	17.52
D1	29.88	28.15	29.88	34.19	31.6	34.47

With this, the researcher used the compressive strength indicated in the General Conditions of the structural drawings for the modelling and structural analysis of the building in SAP2000 which is 28 MPa.

Rapid Visual Assessment Using SCOSSO Application

The approximate seismic vulnerability of the BCE II Building of Sta. Lucia High School was determined with the use of SCOSSO application through rapid visual assessment. The Sta. Lucia High School was constructed in the year 2012. It has a nearby river with a distance of 0.74 km, a nearby coast with a distance of 13.2 km and a nearby fault 2.8 km away. The BCE II Building's classrooms and laboratories are currently used by Grade 7 and Grade 8 students whose total population is 2659 students. This alone indicates that the building is subject to ground shaking as analyzed in the study of Nassirpour and D'Ayala (2018) which indicates that a building more than 675 students and teachers who accommodates makes it more exposed to ground shaking. Based on the rapid visual survey conducted, the BCE II Building of Sta. Lucia High School has six (6) storeys with a 3.15 m storey height. The entire building has 32 classrooms, one (1) library room, one (1) office room, one (1) IT Hub, three (3) hall rooms, one (1) service room, and five (5) other rooms. Each story has an average of 45 openings for the windows, doors, etc. The ground floor comprises of 50% opening due to the design of the corridors. The structural information gathered indicates that it has a primary structural system of Reinforced Concrete Moment Frame. In the structural info, the researchers have indicated one-star (good/fair condition) for the BCE II Building's structural condition, since the school registry's documents also show that most of the rooms need minor repairs and that only three (3) rooms have undergone major repairs for the last five (5) years. The overall building condition also indicates that the BCE II Building needs minor repair, hence the one star on retrofitting.

Table 6. *Estimated vulnerability index of BCE II building of Sta. Lucia high school*

Flood	Earthquake	Wind
53%	66%	45%

As shown in Table 6, the BCE II Building of Sta. Lucia High School has an estimated 66% vulnerability rating for Earthquake hazards. In the study of Nassirpour and D'Ayala in 2018 it was indicated that the year of construction of a building has a crucial role in the assessment of its vulnerability. This study relates to the assessment made since the Sta. Lucia High School's BCE II building was built in 2012. The vulnerability rating acquired is quite high therefore it needs a thorough evaluation similar to the study of D'Ayala et al., (2020) where buildings with vulnerability index greater than 50% are advised to be subject to comprehensive assessment and planning for retrofitting or strengthening. School buildings are one of the vulnerable buildings during an earthquake due to its typical structural design. School buildings have large windows (especially tropical countries), spacious rooms, and corridors. These features cause lower stiffness and results in large lateral displacements of a building during a seismic activity (Nassirpour & D'Ayala 2018).

Determination of Pushover Curve, Capacity Curve, and Response Spectra Using Capacity-Spectrum Method of BCE II Building

Pushover Analysis

The pushover analysis of BCE II building has obtained results along X-direction and Y-direction as shown in Figure 4 and Figure 5. These graphs illustrate a relationship between the base shear force (x-axis) and displacement (y-axis).

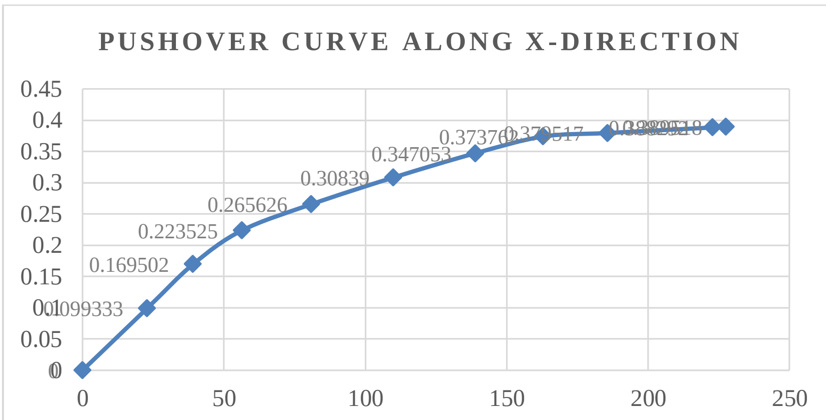

***Figure 4**. Pushover curve along X-direction of the BCE II building*

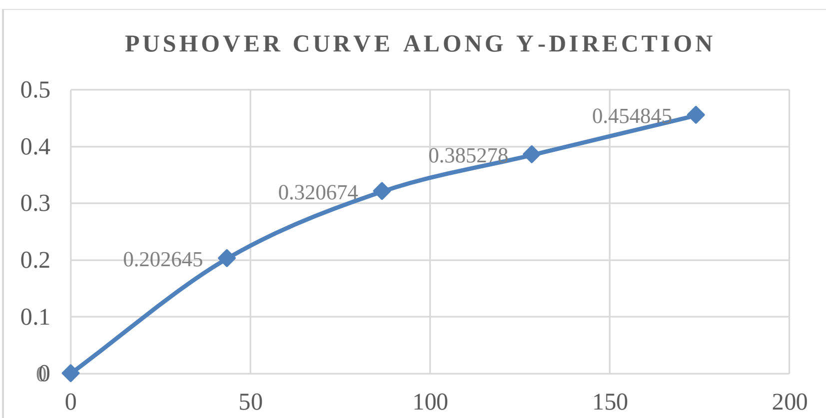

***Figure 5.** Pushover curve along Y-direction of the BCE II building*

According to Pierre and Hidayat (2020), the pushover curve's maximum point corresponds to the capacity of the material structure that can withstand maximum lateral loads. The yield point, on the other hand, pertains to the elastic limit of the structure.

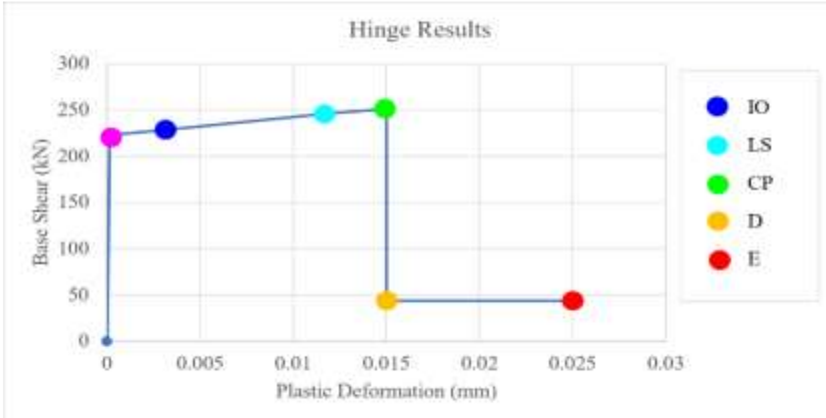

Figure 6. *Hinge results of BCE II building*

The pushover analysis was done to detect the successive damage states of the building which provides not only information on strength but also the structure's deformation and ductility, as well as the distribution of demands which helps in locating the critical members that would reach the limit states once an earthquake occurs. Figure 6 shows the hinge results of the BCE II Building of Sta. Lucia High School wherein the base shear force against the plastic deformation was plotted using the pushover analysis feature of the SAP2000. The performance levels 'Immediate Occupancy' (IO), 'Life Safety' (LS) and 'Collapse Prevention' (CP) of a critical column in the BCE II building were represented in the load versus deformation curve. The graph also presents the force deflection behavior of the hinge.

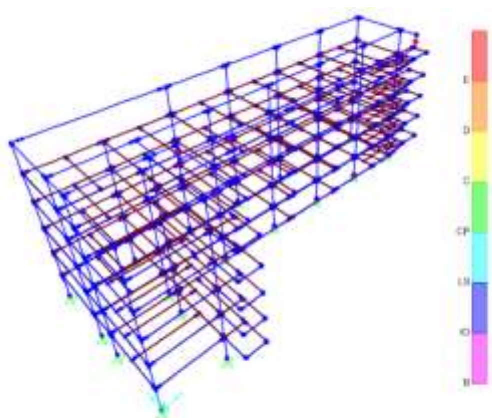

Figure 7. *Deformed shape of BCE II building model*

Figure 7 shows the deformed shape of the BCE II Building of Sta. Lucia High School in SAP2000 after being subjected to the pushover analysis. It shows the location of the hinges and its states according to the color coding on the right side of the model.

Capacity Spectrum Method (CSM)

The performance point refers to the point where the curve of capacity intersects the spectrum response curve as used in the capacity spectrum method (Pierre & Hidayat, 2020). In structural reliability, the performance function can be derived from the two functions: resistance and the load effect. In this paper, capacity curve is the resistance function while the response spectrum represents the load effect. In CSM, this can be captured through the performance points. Figure 8 portrays a superimposed capacity curve based on May 24, 2013 Sea of Okhotsk Earthquake of Magnitude 8.3 in east-west direction at x-axis of the building.

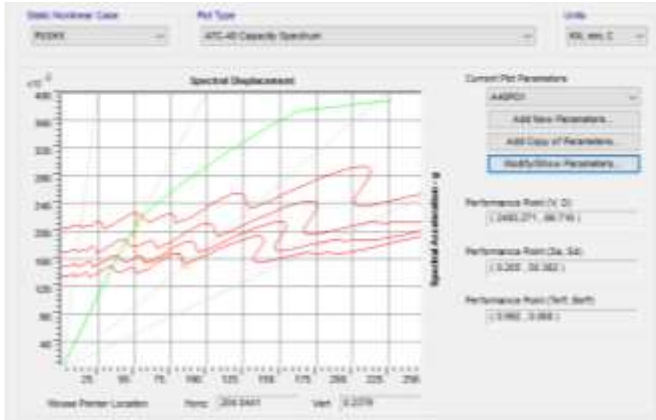

Figure 8 Capacity curve based on sea of Okhotsk earthquake of magnitude 8.3 in EW direction at x-axis of the building

Damage Ratio and Probability of Occurrence

The damage ratio can then be derived from the probability of occurrence by accumulating the probability as it increases in the PGA value. This damage ratio values are used as scatter points in the plot of seismic fragility curves. By plotting the natural logarithm of PGA vs. damage ratio, linear regression parameters can be determined graphically. These parameters can now be used as statistical parameters, that is, mean and standard deviation, for the lognormal function nature of the fragility curves. The damage ratios accumulated were used to create the graph that shows the probability of occurrence as shown in Figure 9 to Figure 12. These graphs demonstrate the percentage of each damage rank corresponding to the PGA.

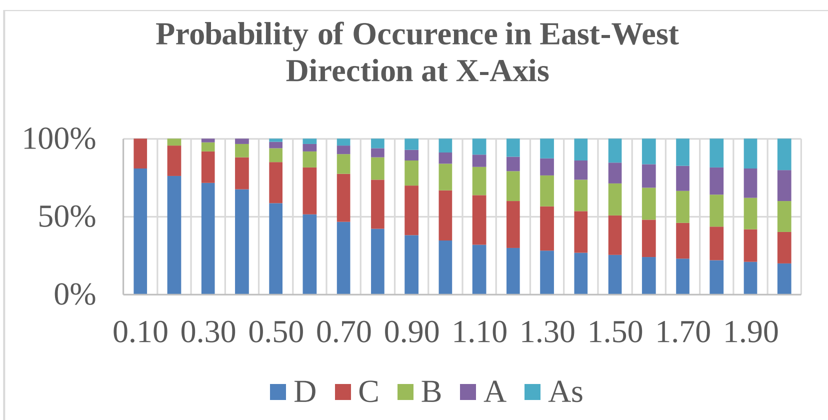

Figure 9. *Probability of occurrence in east-west direction at x-axis*

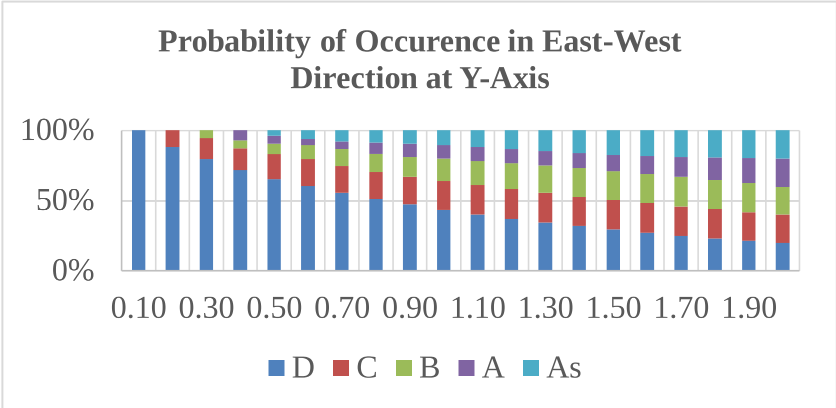

Figure 10. *Probability of occurrence in east-west direction at y-axis*

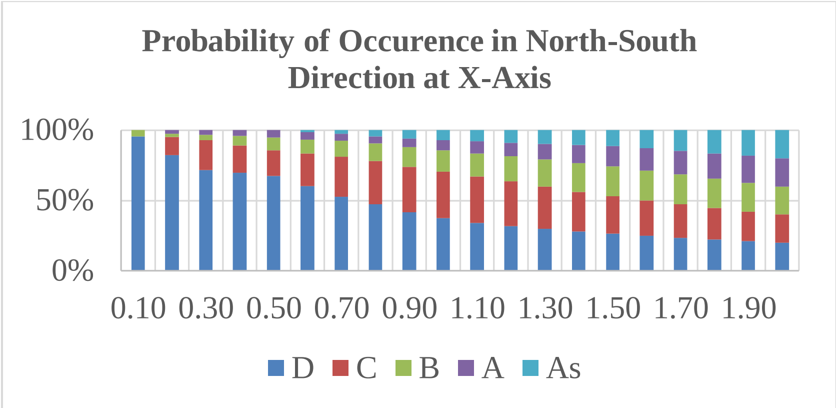

Figure 11. *Probability of occurrence in north-south direction at x-axis*

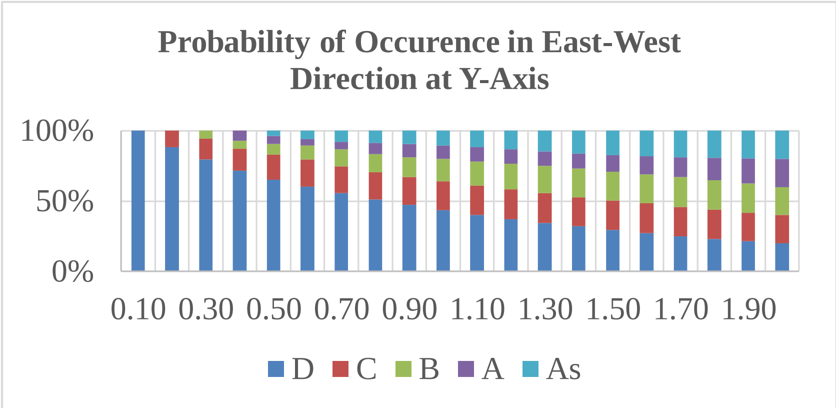

Figure 12. *Probability of occurrence in north-south direction at y-axis*

Fragility Curves

The charts presented are the plot of seismic fragility curves for the BCE II Building of Sta. Lucia High School. In the fragility curves, each of the damage ranks were compared. The Damage Rank D was not included in the fragility analysis since it corresponds to no damage in the structure. In practice, the "No Damage" or "D" damage rank is not included in fragility analysis (Baylon & Marcos, 2018).

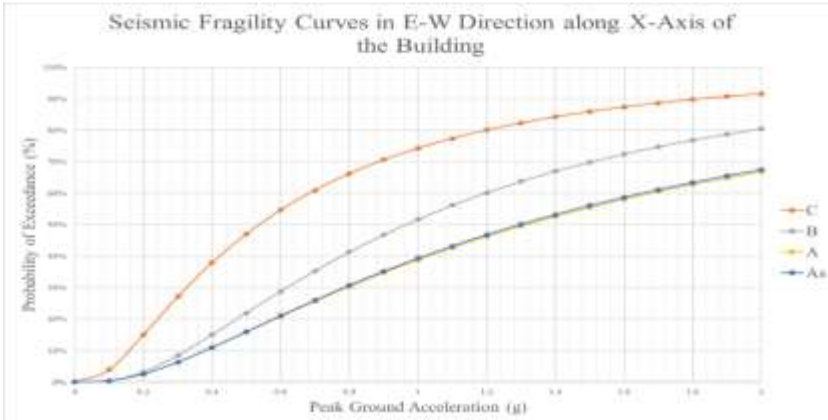

Figure 13. *Seismic fragility curves in EW direction along x-axis of the building*

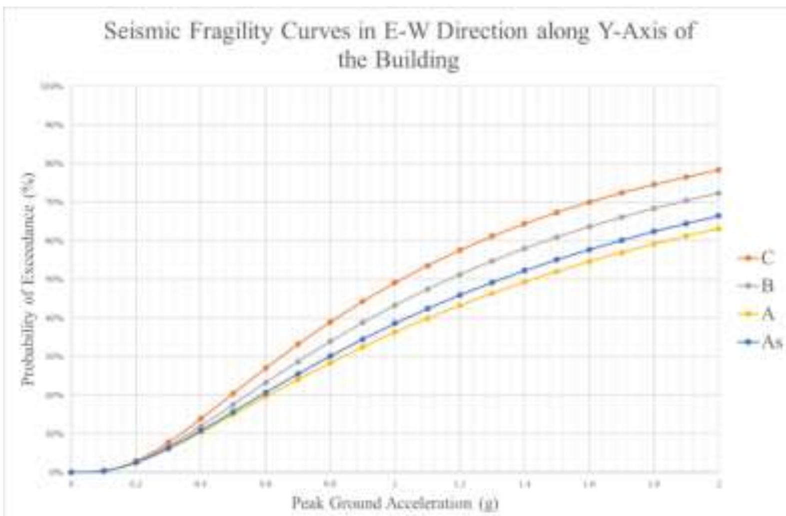

Figure 14. *Seismic fragility curves in east-west direction along y-axis of the building*

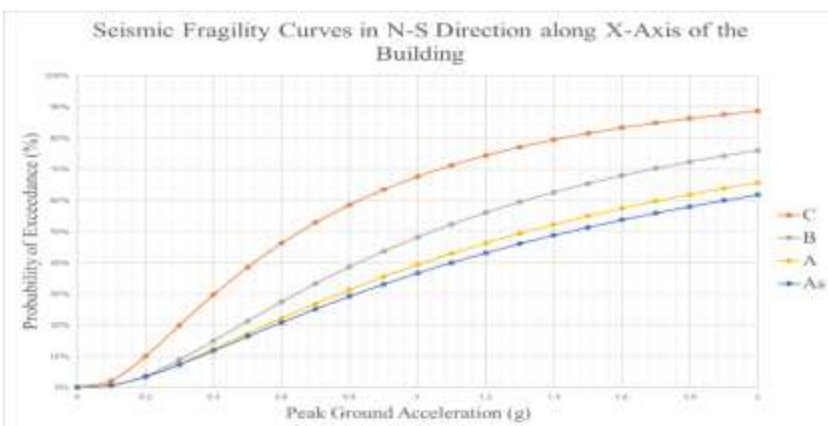

Figure 15*. Seismic fragility curves in north-south direction along x-axis of the building*

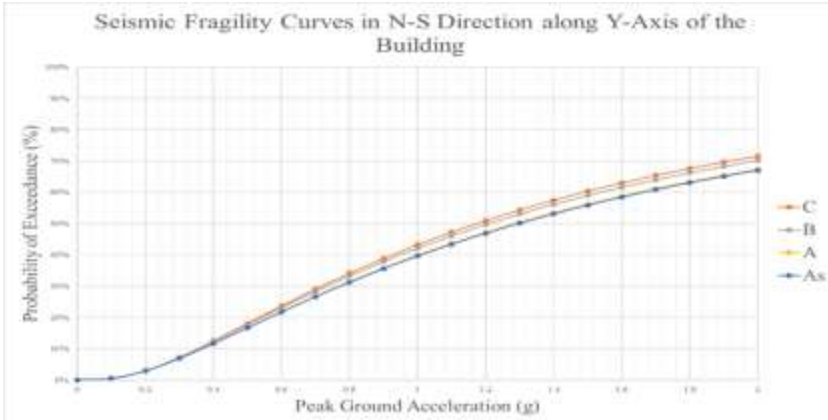

Figure 16. *Seismic fragility curves in north-south direction along x-axis of the building*

Threshold Determination

The structure was subjected to strongest motions of earthquake records from different years which were the Mindanao, Philippines in 2010 with magnitude 7.7, Near Coast of Honshu, Japan in 2011 with magnitude 9.1, and Leyte, Philippines in 2015 with magnitude 6.1, and with different excitations of normalized PGA from the highest peak ground acceleration. These earthquakes were scaled into different PGAs based on the moderate damage state of the building with 10% probability of Exceedance from the fragility curves shown in Table 7.

Table 7. *Peak ground acceleration in g at moderate damage with probability of exceedance of 10%*

Motion of Earthquake	Axis of the Building	PGA (g) at Moderate Damage with PoE of 10%
North-South	X	0.322
East-West	X	0.324
North-South	Y	0.357
East-West	Y	0.364

Using the Nonlinear Dynamic Analysis, also known as the Time History Analysis, different responses from the structure were determined: the relationship between displacement and base shear, time and acceleration, time and base shear, and time and displacement. The peak ground acceleration in which the structure will be moderately damaged can be determined from the absolute maximum responses after subjecting the structure to the ground motion data of the earthquakes stated. The maximum responses can be seen in the result of relationship of time and acceleration in different directions of the earthquakes at different axes of the building.

Table 8. *Performance-based threshold of the BCE II building of Sta. Lucia high school for moderate damage rank with 10% probability of exceedance at X-Axis of the building*

Acceleration Ux	Threshold Pga (G)
0.322 g NS (X)	0.238
0.324 g EW (X)	0.255
0.357 g NS (Y)	0.259
0.364 g EW (Y)	0.240

Table 9. *Performance-based threshold of the BCE II building for moderate damage rank with 10% probability of exceedance at Y-Axis of the building*

Acceleration Uy	Threshold Pga (G)
0.322 g NS (X)	0.055
0.324 g EW (X)	0.099
0.357 g NS (Y)	0.094
0.364 g EW (Y)	0.123

Table 8 and Table 9 show that after subjecting the building to the scaled peak ground acceleration based on the moderate damage rank with 10% probability of exceedance from the fragility curves of the three (3) ground motion data, the following thresholds were acquired at the x and y -axis of the building. To summarize the data the structure is expected to attain moderate damage along x-axis with PGA of 0.322g in north-south direction of the earthquake along x-axis of 0.238g. For the y-axis, structure is expected to attain moderate damage with PGA of 0.322g in north-south direction of the earthquake along x-axis of 0.055g.

CONCLUSIONS AND RECOMMENDATIONS

The model of the structure in SAP2000 was easily generated through the use of the existing as-built plans. There was a minor discrepancy between the compressive strength obtained from Schmidt rebound hammer test and the compressive strength indicated in the as-built plans. The BCE II Building of Sta. Lucia High School obtained an estimated seismic vulnerability index of 66% in the Rapid Visual Assessment through SCOSSO application, which was evaluated to be highly vulnerable and subjected to thorough assessment. The pushover analysis results implied that the BCE II Building of Sta. Lucia High School can withstand a larger base shear force along the Y-Axis of the building compared to the X-Axis which makes it to be the stronger axis. The structure will attain its completely damaged state at a PGA of 0.352g or greater with a probability of exceedance of 10% which takes place in north-south direction of the earthquake along x-axis. The structure is limited only to 0.3g which is lower than the minimum requirement stated in the National Structural Code of the Philippines which is 0.4g. Furthermore, the fragility curves show that as the PGA gets stronger, the higher the chance of the building to collapse. For the thresholds, the structure is expected to attain moderate damage along x-axis with PGA of 0.322g in north-south direction of the earthquake along x-axis of 0.238g. Along the y-axis, structure is expected to attain moderate damage with PGA of 0.322g in north-south direction of the earthquake along x-axis of 0.055g. The peak ground acceleration of the BCE II Building of Sta. Lucia High School was found to be 0.352g which can withstand up to Intensity VIII earthquake based on Modified Mercalli Intensity Scale or up to Magnitude 6.0-6.9 earthquake according to the table of USGS website in 2020. And from the fragility curves, it has a high probability of getting moderately damaged at the stated earthquake magnitude and intensity with at most peak ground acceleration of 0.352g.

The present method considered only to 2.0 g earthquake PGA and to a maximum of 20 ground motion data. With this, the following are suggested:

1. Results are based only on the as-built plans which only give the compressive strength of the concrete, dimensions of the columns, actual elevations and the sizes of the beams of the structure. It is recommended to perform other tests that will also consider the tensile strength of the building.
2. Use of computer software such as, but not limited to SAP2000 and MS Excel is highly recommended for this study. The researchers believe that latest versions of MIDAS Gen., ETABS, SEISMOSTRUCT, SEISMOBUILD or PROTA STRUCTURE can make the approach more efficient.
3. Future researchers are recommended to assess the structure and give the thresholds where the building will likely be slightly to extensively damaged.

4. For the school administrators, raise awareness regarding the BCE II building situation to ensure the safety of the school's occupants in case of an earthquake. Similarly, the local government should prioritize the Sta. Lucia High School in their future projects involving the retrofitting of public-school buildings due to its high earthquake vulnerability index.
5. Lastly, as per the SCOSSO Application where the structure was found out to be vulnerable to seismic activities, the proponents of this study recommend retrofitting the BCE II Building of Sta. Lucia High School to meet the requirements of the National Structural Code of the Philippines.

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