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Base Isolation System: Innovative Design Procedure for Building of Don Honorio Ventura State University (DHVSU) - Lubao Campus

John Lerrie S. Dabu[1], Alexa Danielle D. Regala[1], Ryan Christopher N. David[1], Cristian Kelly C. Dabu[1], Marvin S. Millan[1], Angel Franz L. Soriano[1], Inla Diana C. Salonga[1], Rowel D. Waje[1], Ma. Luz Q Manuntag[1]*

[1]College of Engineering and Architecture Department of Engineering, Don Honorio Ventura Technological State University Cabambangan, Bacolor, Pampanga, Philippines.

Corresponding Author: 2018005456@dhvsu.edu.ph

Abstract: - Powerful earthquakes pose the biggest threats to structures. As a way to break this dilemma, vibration-control measures have been developed. One of the seismic design methods is the Base Isolation Method, also known as Seismic Base Isolation. It is a great way to protect structures from the destructive power of earthquakes. The isolators partially reflect and absorb incoming seismic energy before it is transmitted to the superstructure. An Elastomeric Rubber Bearing Isolator was introduced in this study. Films of rubber with substantially lesser horizontal stiffness are inserted between the superstructure and the foundation. This paper presents the effectiveness of Base Isolation using Elastomeric Rubber Bearing on the future buildings within the Don Honorio Ventura State University - Lubao Campus under the National Structural Code of the Philippines 2015. Linear Dynamic Analysis (Response Spectrum Method) and Nonlinear Dynamic Analysis (Time History Analysis) are used for the design method of this study. A comparative analysis has also been performed between the Base-Isolated and Fixed-Base Structure using Modal Analysis and Dynamic Analysis. With the use of STAAD Software, a three-story structure with a base isolation system is designed. The dynamic properties were compared in different parameters such as modal analysis, dynamic response, base shear, and story drift. The results of the base-isolated structure have successfully passed all the tests, while the fixed-base structure failed on a few assessments. The results show that the proposed technique lessens lateral displacements and possible damages due to seismic forces. Thus, the Base Isolation Method has proven to be an effective earthquake-resisting design method.

Key Words: ***Base Isolation, Elastomeric Rubber Bearing, Modal Analysis, Response Spectrum Method, STAAD Software, Time History Analysis.***

I. INTRODUCTION

A ground movement that occurs spontaneously and gradually continues, which causes tragedies such as fatalities and breakdown of structures, is known as earthquake. From this seismic activity, the energy that has been released makes waves. These two waves are primary (P waves) and secondary waves (S waves). Manoharan et. al. (2021) stated that these waves produce ground movement when an earthquake occurs, which is then transferred to the surface of a specific part of a structure called the foundation. Cracks and settlements can be seen on a structure after the vibration of the ground depending on the intensity of the earthquake. Damage to structure increases along with the ground motion caused by force-induced from the surface.

Hamakareem (2009) affirmed that inertia forces are generated when an earthquake strikes a structure, which may be extremely destructive, causing minor to major deformation during and after shaking. One of the seismic impacts that have a detrimental effect on a building is the production of inertia, this refers to the tendency of the roof to remain in initial position.

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The foundation moves when a structure swings due to an earthquake while the roof remains fixed. Inertia force will cause the weak walls or joints to shear that eventually fail and collapse.

Thorat (2014) stated that the highest point where any solid material can withstand before the deformation is called the Elastic limit. Changes take place when this elastic limit is exceeded. Once the load is removed, these changes are permanent and irreversible. These impacts can be substantial and a crack emerges when concrete surpasses its elastic limit in tension or gradually when the flange of a steel girder yields. Therefore, the use of ductility by structural engineers to cause a higher deformation of the structure is acceptable. It is feasible to achieve more deformation on the buildings than the permissible elastic limit by increasing the modest sum of forces. Nonetheless, ductility might reasonably harm the structure. However, if additional elasticity is applied to the structure, it will cause an increase in the total cost of the structure and increase the strength to reduce the damage. As a result, the components of the structure may get damaged if the strength is reduced.

Earthquakes are an unforeseen occurrence if the structure is in a seismically active region. The structural engineer needs to take action in order to save lives and cause the least amount of damage to structures when an earthquake happens. Anti-seismic designs for structures have been introduced over the years. The recent effective seismic response on how to deal with earthquake damage to buildings is the base isolation system. This may not totally prevent the damage to structures caused by an earthquake but would aid in maintaining the impact to its minimum extent.

Over the last few years, base isolation has become increasingly popular. Being used in structures and bridges has existed for decades. Paul (2016) stated that base isolation is a cost-effective and easy form of seismic protection for buildings. It is attained by isolating or separating the superstructure from its substructure that is standing on trembling ground. The seismic energy is deflected and dissipated by the base isolation, lowering the intrinsic frequency of the structure. As a result, the base isolation reduces the displacement and protects the stability of the structure.

The idea of isolating the structure from the ground to prevent earthquake damage seems relatively easy. Yet, no one has figured out how to deal with the challenges that come from ideal isolation systems. Kelly (2001) stated that, meanwhile, earthquakes are having a devastating impact on buildings and their contents, even in well-designed structures. However, these remarks are not only about ideas but rather practical isolation systems, systems that achieve a balance between ground attachment to resist gravity and ground separation to withstand earthquakes.

Base-isolation lengthens the natural period of a structure and minimizes the displacement of the structure during earthquake occurrence. Different types of base isolation techniques have been developed over the years, each prepared for particular seismic events and buildings. Warrier et al. (2016) stated that elastomeric and sliding bases are the two main types of base isolation techniques. During an earthquake, both systems are intended to withstand the weight of the building and allow the foundations to slide sideways. This accelerated the lifespan of the building, and base displacement was more than prescribed limits.

The elastomeric bearing isolator, which fits under the first type, is the main focus of this paper. It is a layer of rubber with substantially lower horizontal stiffness that had been inserted between the superstructure and the foundation. The lifespan of the system is significantly greater than the preset base natural duration following isolation.

II. METHODOLOGY

2.1 Data Gathering

Different data are required to design a new structure, especially when creating a base-isolated building. The information and studies are also obtained from the internet and books. The data on national building specifications and traditional design of school buildings in the Philippines is also acquired in order to create and improve the design of the building.

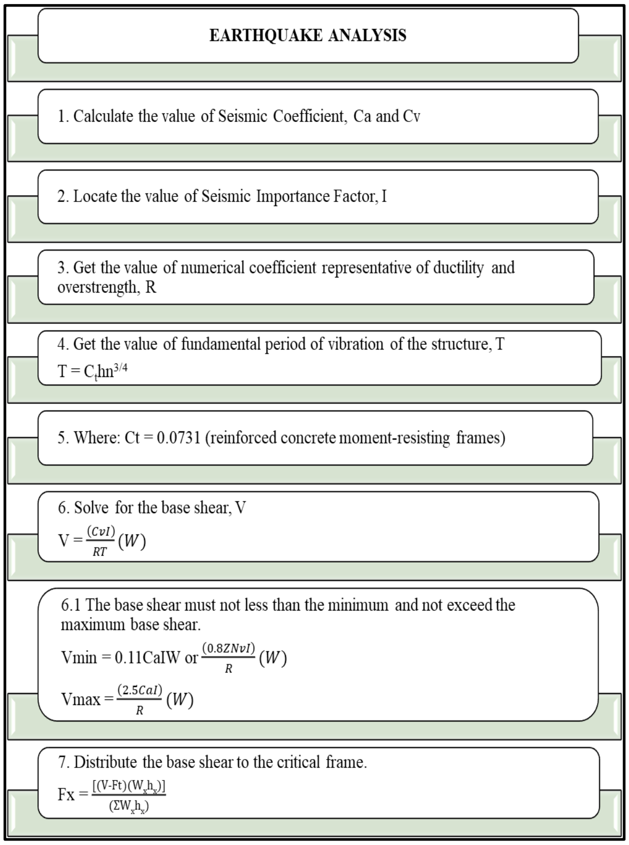
The National Structural Code of the Philippines 2015 (NSCP 2015) was used to establish the proper design specification needed to improve school buildings in the Philippines. These are the dead load, live load, wind load, and also seismic load that the structure will sustain.

The provided structural and architectural plans from Office of Physical Plant and Facilities (OPPF) of Don Honorio Ventura State University (DHVSU) were gathered as the guide of this study. Also, the proposed dimensions of beams and columns were analyzed according to the different comparative parameters to be used.

2.2 Earthquake Analysis

The study assumed the dimensions of the parts of the structure for the weight of the building and solved the earthquake analysis of the structure, as shown in Fig.1.

The following details are the steps to determine the load due to earthquake:



EARTHQUAKE ANALYSIS

1. Calculate the value of Seismic Coefficient, Ca and Cv

2. Locate the value of Seismic Importance Factor, I

3. Get the value of numerical coefficient representative of ductility and overstrength, R

4. Get the value of fundamental period of vibration of the structure, T

$T = C_t hn^{3/4}$

5. Where: Ct = 0.0731 (reinforced concrete moment-resisting frames)

6. Solve for the base shear, V

$V = \frac{(CvI)}{RT}(W)$

6.1 The base shear must not less than the minimum and not exceed the maximum base shear.

$Vmin = 0.11CaIW \text{ or } \frac{(0.8ZNvI)}{R}(W)$

$Vmax = \frac{(2.5CaI)}{R}(W)$

7. Distribute the base shear to the critical frame.

$Fx = \frac{[(V\text{-}Ft)(W_x h_x)]}{(\Sigma W_x h_x)}$

Fig.1. Steps on Solving the Load Due to Earthquake

2.2.1 Linear Dynamic Analysis (Response Spectrum Method)

The response spectrum method, shown in Fig.2., was used to calculate the linear dynamic analysis. For structural design purposes, it is accurate to directly compute the peak reaction of a structure from the seismic response during an earthquake.

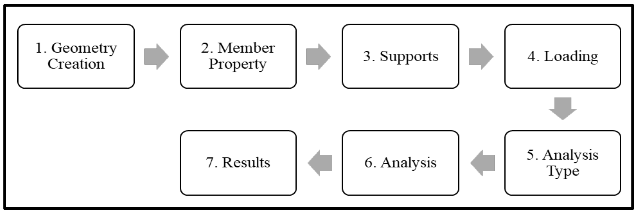
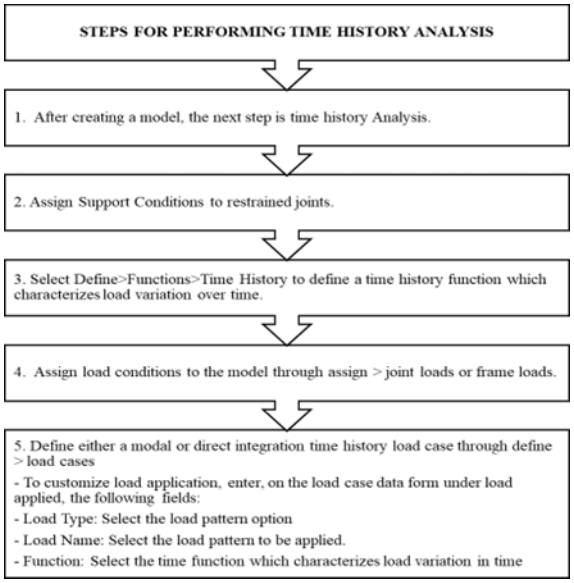


Fig.2. Flow Chart of Response Spectrum Method

2.2.2 Nonlinear Dynamic Analysis (Time History Analysis)

Time History Analysis (THA) is a significant technique for the seismic analysis of structure, especially if the structural response examined is nonlinear. When evaluating a structure, it is necessary to have a realistic seismic time history of performing the analysis. As shown in Fig.3., the time history analysis is a step-by-step analysis of the dynamic response of a building to a given loading that may alter over time. Therefore, it is used to evaluate the seismic reaction of a structure under dynamic loads from an indicated earthquake.



STEPS FOR PERFORMING TIME HISTORY ANALYSIS

1. After creating a model, the next step is time history Analysis.

2. Assign Support Conditions to restrained joints.

3. Select Define>Functions>Time History to define a time history function which characterizes load variation over time.

4. Assign load conditions to the model through assign > joint loads or frame loads.

5. Define either a modal or direct integration time history load case through define > load cases

- To customize load application, enter, on the load case data form under load applied, the following fields:
- Load Type: Select the load pattern option
- Load Name: Select the load pattern to be applied.
- Function: Select the time function which characterizes load variation in time

Fig.3. Illustration of Time History Analysis Method

There are six (6) mode shapes that will be used through this method. The behavior of each mode shape is described in Table 1.

2.3 Modal Analysis

The analysis of the dynamic properties of structures under vibration stimulation is well known as modal analysis. Modal analysis is known in structural engineering that uses the overall mass and firmness of a structure to determine the different times when it will dynamically resonate.

The two said design approaches were used in this analysis.

Table.1. Behavior of each mode shape

Mode Shapes	Behavior
1	Half wave with movement in the global Z-direction
2	Half wave with movement in the global Y-direction
3	Full wave with movement in the global Z-direction
4	Twisting mode about the longitudinal axis of the beam
5	Full wave with movement in the global Y-direction
6	1.5 waves with movement in the global Z-direction

2.3.1 Comparative Analysis between Fixed-Base Structure and Base-Isolated Structure

The Structural Analysis and Design Program (STAAD Pro), is a generally used software specifically built-in structure design and analysis such as buildings, bridges, transit, and other infrastructures. STAAD Pro assists structural engineers in virtual design and analyzing any type of structure without the laborious and time-consuming manual computation. The application mentioned will be compared to assess the seismic performance of the designed 3-storey building between these two situations, the base isolation method and the fixed-base method. The two said approaches will be run on the application to determine if there is a significant difference if base isolation will be implemented rather than traditional fixed-base structures.

Fig.4. is the illustration of model generation and Design Steps. These are the simplified steps for generating and analyzing the model of the structure using STAAD Software.

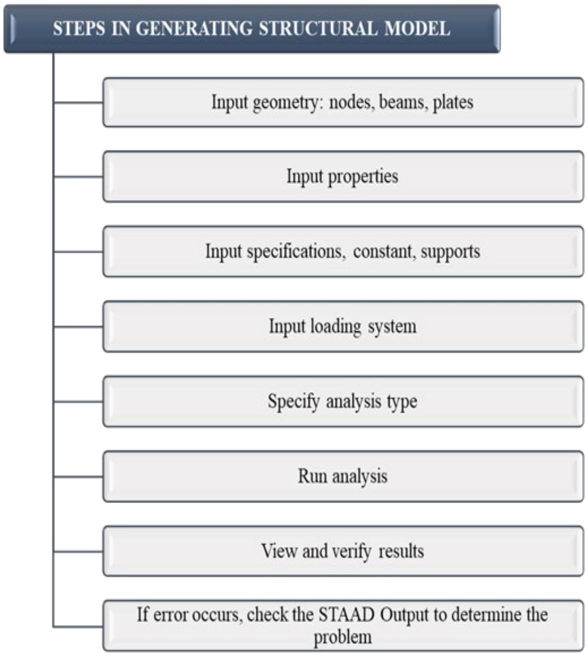


Fig.4. Illustration of Model Generation and Design Steps

2.4 Mathematical Computations

A mathematical calculation has been performed before re-running the two design approaches for the base of a structure. Calculating the stiffness of the mentioned isolator led to the creation of the spring coefficients for the Elastomer Bearing needed for STAAD Pro. In line with this, STAAD Pro was used to obtain dynamic properties of a structure, such as vibration analysis. A 3-storey building was modeled with a base isolator settled on it. Acceleration, velocity, and displacement were also determined.

Understanding the overall displacement and acceleration of the structure during an earthquake can help to keep it from collapsing. By equating the acceleration and displacement of a structure, the damage that various structures inflict on one another during an earthquake is minimized.

The buckling of the structure, or the displacement of the mass with respect to the moving mass, is the highest interest in structural engineering, having internal forces which are directly connected to the ground.

Story drift is the lateral displacement or the perpendicular distance displacement of a floor relative to the floor below. The formula below will be utilized to calculate the story drift (Δs) of the target building.

$$\Delta s = \frac{\Delta m}{(0.7 \text{ x } R)}$$

$$\Delta s = \frac{0.025}{0.7\text{x}8.5} = 0.0042$$

where:

$\Delta m = 0.025h$ or $h/40$, if $T < 0.70$ sec.

$\Delta m = 0.020h$ or $h/50$, if $T > 0.70$ sec.

T = fundamental period of the building

h = structural height

$Ct = 0.0731$ for concrete SMRF

$$T = Ct(hn)^{3/4}$$

$$T = 0.0731(9)^{3/4}$$

$$T = 0.37984 \text{ sec}$$

2.5 Elastomeric Bearings

Elastomeric bearings are steel plate laminated elastic bearings inserted between the frame of a vessel and its modules. The stiffness of the link is computed in the equations below with given properties in Table 2.

Table 2 defines the property of elastomeric bearing for structures A and B. These are used as the design of the base isolator, including the measurement of each part, area thickness, and strength. Given values are examined systematically for possible desired results and redesigned if there are any errors obtained from software.

The isolators sustain corresponding minor shear strain on older $\gamma = 0.2$ for compressive stresses under vertical loads. Thus, shear modulus = 680000 Pa will be applied in the equation, and the shape factor is determined as 12.3. The compression modulus from the equation is given as:

$$Ec = \left(\frac{1}{6GS^2} + \frac{1}{K}\right)^{-1}$$

Where:

Ec: Compression Modulus,

S: Shape Factor (5< S < 30)

K: Bulk Modulus (1000MPa < K < 2500 MPa),

G: Shear Modulus (0.5MPa < G < 2.5 MPa)

$$Ec = (\frac{(6)(680)(12.3)^2 \ x\ 2000000}{(6)(680)(12.3)^2 + 2000000}$$

$$Ec = 471685.9963\ kN/m^2$$

For Structure A:

$$\mathrm{Kh} = \mathrm{keff} = \frac{\mathrm{Geff(A)}}{\mathrm{Hr}} = \frac{680(1)}{0.08} = 8500\ \mathrm{kN/m}$$

$$\mathrm{Kv} = \frac{\mathrm{Ec(A)}}{\mathrm{H}} = \frac{471686(1)}{0.2} = 2358430\ \mathrm{kN/m}$$

For Structure B:

$$\mathrm{Kh} = \mathrm{keff} = \frac{\mathrm{Geff(A)}}{\mathrm{Hr}} = \frac{680(0.1575)}{0.061} = 1755.74\ \mathrm{kN/m}$$

$$\mathrm{Kv} = \frac{\mathrm{Ec(A)}}{\mathrm{H}} = \frac{471686(0.1575)}{0.085} = 874006.41\ \mathrm{kN/m}$$

Kh and Kv denote the lateral and vertical stiffness of the elastomeric pads utilized in the proposed base-isolated structure.

Table.2. Properties of Elastomeric Bearing for Structure A and B

Property	Structure A	Structure B
Elastomer Bearing Length L (m)	1	0.45
Elastomer Bearing Width W (m)	1	0.35
Elastomer Bearing Height H (m)	0.2	0.085
Total elastomer thickness hr (m)	0.08	0.061
Thickness of one elastomer layer hri(m)	0.01	0.008
Thickness of one steel reinforcement layer hs (m)	0.005	0.003
Elastomer gross plan area A (m^2)	1	0.1575
Shape Factor S	12.3	12.3
Compression Modulus Ec (kPa)	471686	471686
Shear Modulus G (kPa)	680	680

2.6 Modeling of the Building Structure

Table 3 shows the dimensions, specifications, and information needed to design the two structures using the STAAD Pro V8i SS6 software.

Table.3. Description of the buildings A and B

Type of Structure	Low Rise RCC Frame Structure
Occupancy	Academic School Building
Number of storeys	3
Foundation depth	3 m
Intermediate storey height	3 m
Type of soil	Soft soil
Length of building	47 m
Height of building	9 m
Column Size	0.45 m x 0.45 m (A) 0.35 m x 0.35 m (B)
Beam Size	0.35 m x 0.45 m (A) 0.35 m x 0.35 m (B)
Slab Thickness	0.125 m
Code	UBC 1997, NSCP2015

The structural plan and elevation of the building are modeled using the software, as shown in Fig.5. and Fig.6.

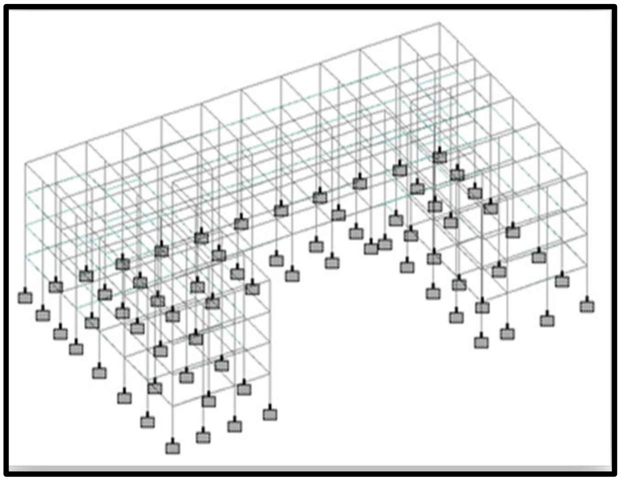


Fig.5. Elevation of the Structure

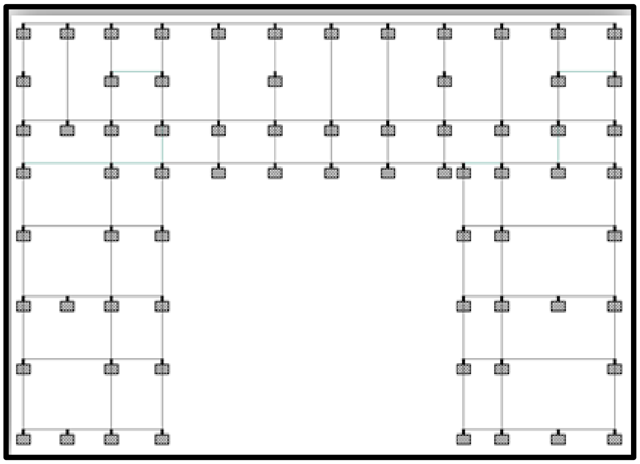


Fig.6. Plan of the Structure

2.7 Assigning Property

Assigning the dimensions of columns and beams in modeling the structure are uniformly distributed, as shown in Fig.7. and Fig.8., respectively.

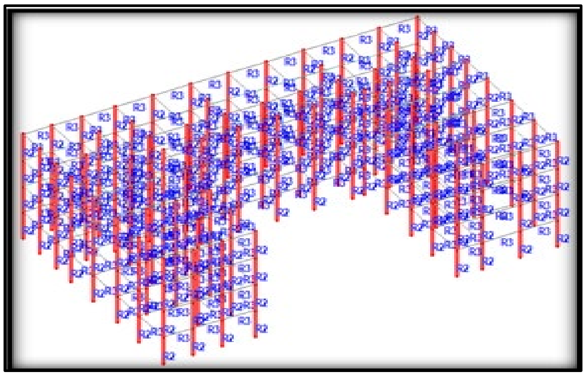


Fig.7. Assigning Columns

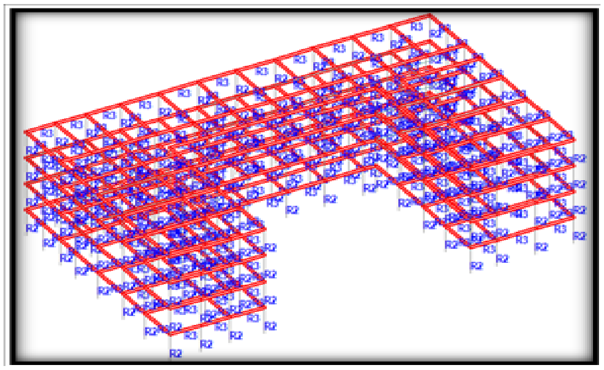


Fig.8. Assigning Beams

2.8 Assigning Supports

The selected supports of the structure are fixed-base and base-isolated to perform the comparative analysis, as shown in Figures 2.9 and 2.10, respectively. The proposed base isolation system is modeled using spring support.

2.8.1. Fixed-Based Support

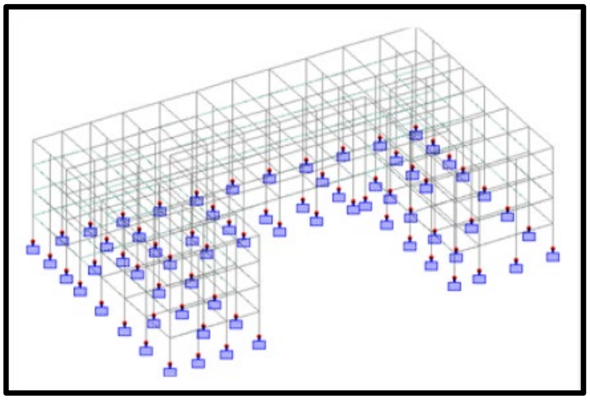


Fig.9. Fixed-Base Support

2.8.2. Base-Isolated Support

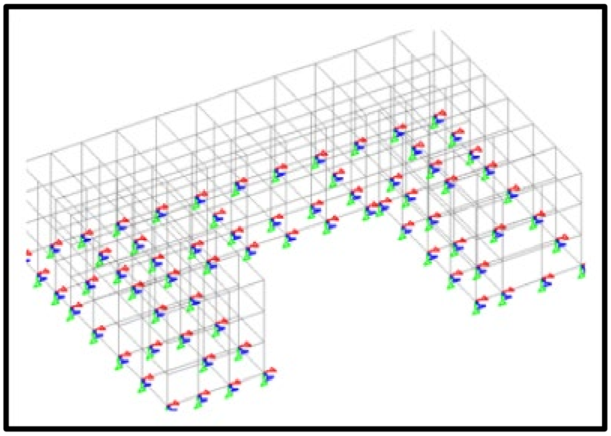


Fig.10. Base-Isolated Support

III. RESULTS AND DISCUSSION

3.1 Non-Linear Dynamic Analysis (Time History Analysis)

Tables 4, 5, and 6 summarize the time THA for the conventional FBS compared with the innovative approach, which is the base isolation technique. The results were generated under different loading conditions and combinations at Structure A. The summary includes time history for displacement, velocity, acceleration at the ground floor level and the top level of both structures. Node number 285 of the modeled structure is located nine meters above the natural grade line, while node number 72 is at the ground level.

Table.4. Time History Displacement - Structure A

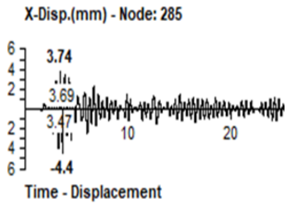
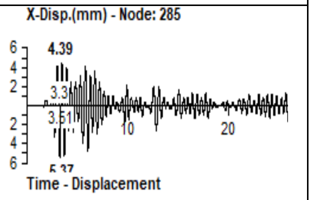
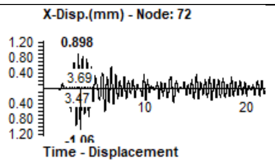
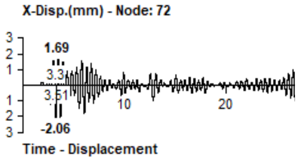
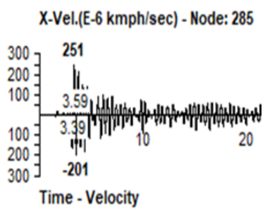
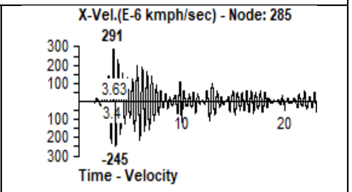
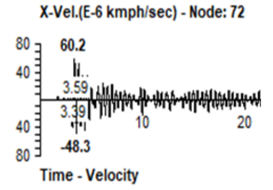
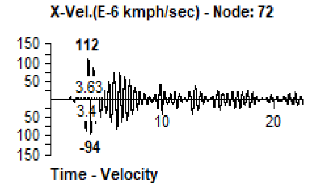
Fixed-Base	Base-Isolated
At Roof Level	
	
At Ground Level	
	

Table.5. Time History Velocity - Structure A

Fixed-Base	Base-Isolated
At Roof Level	
	
At Ground Level	
	

Tables 7, 8, and 9 summarize the THA for the structure with reduced isolator, beam, and girder dimensions labeled as Structure B. Similar to Structure A, the nodes selected for examination of results for the THA are nodes number 285, which is at the top level, and node 72 at the ground level.

Table.6. Time History Acceleration - Structure A

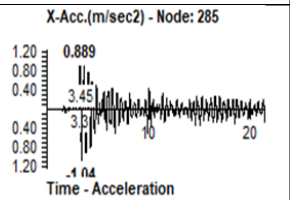
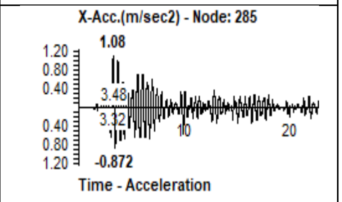
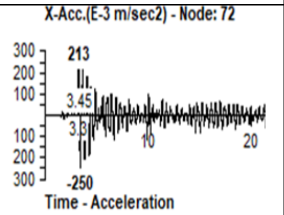
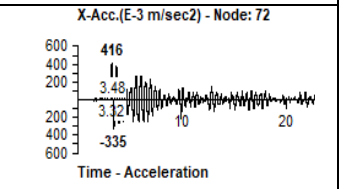
Fixed-Base	Base-Isolated
At Roof Level	
	
At Ground Level	
	

Table.7. Time History Displacement - Structure B

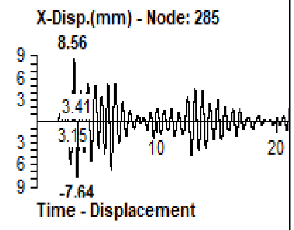
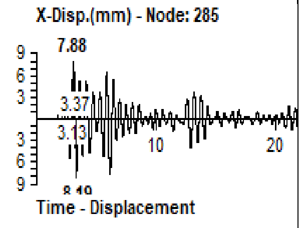
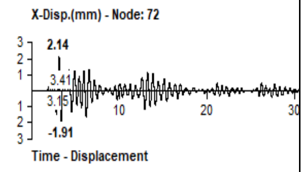
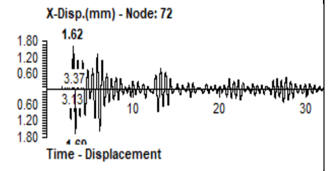
Fixed-Base	Base-Isolated
At Roof Level	
	
At Ground Level	
	

Table.8. Time History Velocity - Structure B

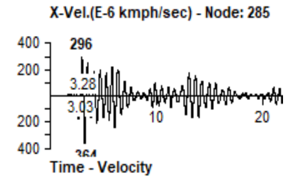
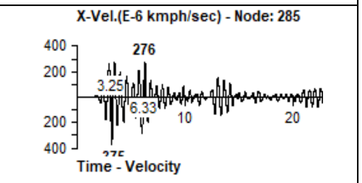
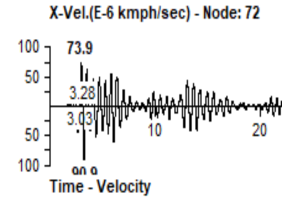
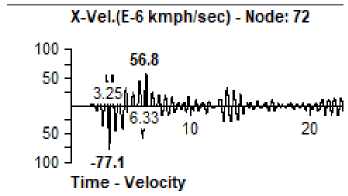
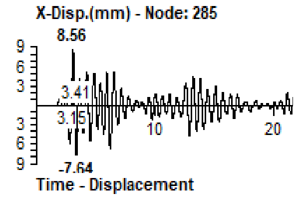
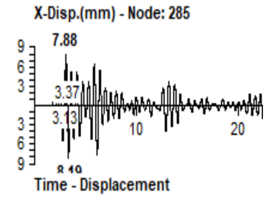
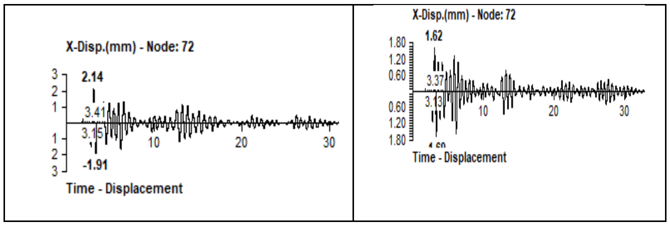
Fixed-Base	Base-Isolated
At Roof Level	
	
At Ground Level	
	

Table.9. Time History Acceleration - Structure B

Fixed-Base	Base-Isolated
At Roof Level	
	
At Ground Level	



The data shown in the tables suggest that the results taken from the base-isolated system were lesser in value than the fixed-base system making the structure safer during the simulated ground motion.

3.2 Linear Dynamic Analysis (response Spectrum Analysis)

The comparison of results taken from STAAD software between BIS and FBS is tabulated in Table 10 for Structure A and Table 11 for Structure B. The base shear at each model in three directions are listed within six (6) modes.

Table.10. Base Shear Comparison for Structure A

Mode	Base Shear at Structure A (KN)					
	Fixed-Base			Base-Isolated		
	X	Y	Z	X	Y	Z
1	5681.68	0	9491.73	1762.54	0	13173.86
2	14449.89	0	4886.16	19738.41	0	1619.19
3	659.85	0	5722.82	190.85	0	6989.61
4	599.84	0	1116.79	399.47	0	262.78
5	35.73	0	224.90	0.71	0	76.17
6	6.44	0	55.96	4.15	0	24.59

Table.11. Base Shear Comparison for Structure B

Mode	Base Shear at Structure B (KN)					
	Fixed-Base			Base-Isolated		
	X	Y	Z	X	Y	Z
1	3517.79	0	8305.14	3862.59	0	6193.63
2	12620.35	0	2828.21	8867.50	0	4019.51
3	108.46	0	5300.00	419.46	0	3019.75
4	258.05	0	126.13	71.03	0	29.03
5	8.38	0	83.69	6.64	0	4.61
6	2.10	0	12.37	0.69	0	4.95

Fig.11. illustrates the base shear at the fixed-base structure and base-isolated structure by the obtained result in the x-direction for Structure A. In terms of lateral forces, the height of the building is where the base shear is distributed. Compared to fixed conditions, using base isolation in a structure minimizes the shear forces. The values decreased by 35.56% at the sixth mode shape and 68.98% at the first mode shape. Therefore, it is an effective method to reduce the impact of seismic events.

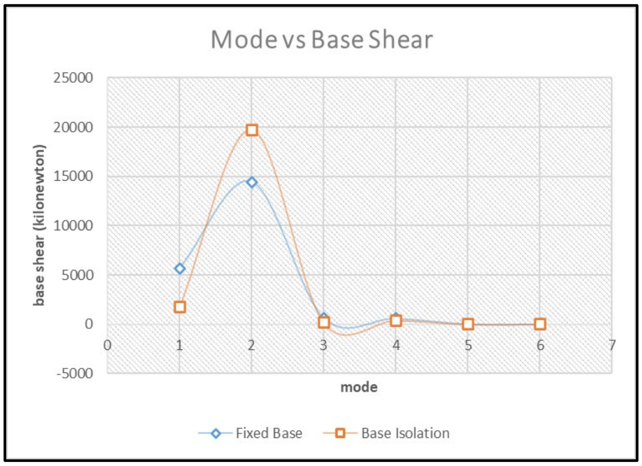


Fig.11. Mode vs. Base Shear for Structure A

The results from Fig.12. showed that the base shear per the mode of base-isolated building for structure B has decreased based on RSA. It indicated that reducing lateral stresses brought on by seismic activity will be required for safety and to reduce the risk that some parts of the building would experience damage.

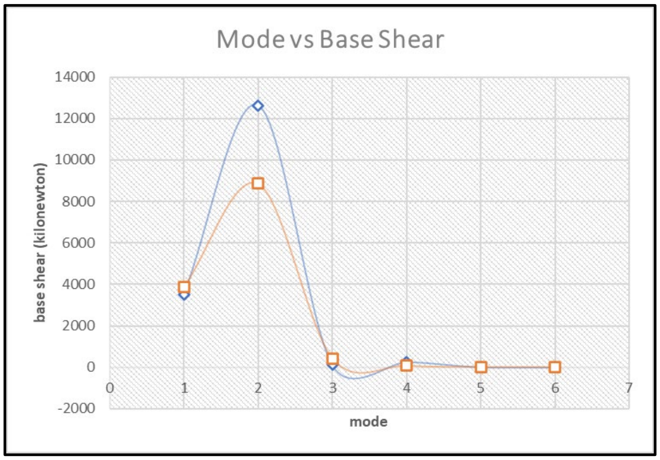


Fig.12. Mode vs. Base Shear for Structure B

3.3 Story Drift

The lateral displacement of each floor with respect to its preceding floors is listed in Table 12 and Figures 13 displays the graphical comparison between distance and story drift of Fixed-Base Structure and Base-Isolated Structure for Structure A.

Table.12. Story Drift Comparison for Structure A

Story	Height (m)	Story Drift at X-Direction (cm)			
		Fixed-Base		Base-Isolated	
		Value	Status	Value	Status
Foundation Level	0	0.0000	Pass	0.0000	Pass
Ground Floor	3	0.4496	Pass	0.0000	Pass
2nd Floor	6	0.6592	Pass	0.6014	Pass
3rd Floor	9	0.5022	Pass	0.5279	Pass
Roof Level	12	0.2481	Pass	0.2753	Pass

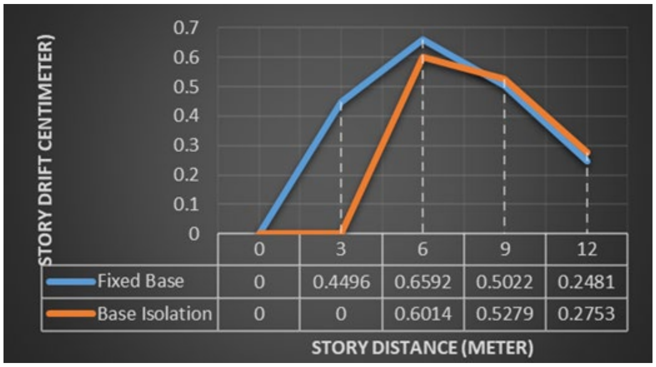


Fig.13.Distance vs. Story Drift for structure A

The data indicates that buildings with base isolation experience minimal story drift compared to traditional fixed-base buildings. The proposed structure is observed to have zero ground-level drift, but the fixed-base structure increased by 0.45 centimeters. These results show that the base isolation technique effectively reduces the sideway deflection transmitted through the building during lateral ground movements.

Table.13. lists the story drift comparison for Structure B and Figure 14 displays the graphical presentation between distance and storey drift for Structure B.

Table.13. Story Drift Comparison for Structure B

Story	Height (m)	Story Drift at X-Direction (cm)			
		Fixed-Base		Base-Isolated	
		Value	Status	Value	Status
Foundation Level	0	0.0000	Pass	0.0000	Pass
Ground Floor	3	0.9611	Pass	0.0000	Pass
2nd Floor	6	1.3552	Fail	1.2337	Pass
3rd Floor	9	1.0000	Pass	1.0649	Pass
Roof Level	12	0.4556	Pass	0.5168	Pass

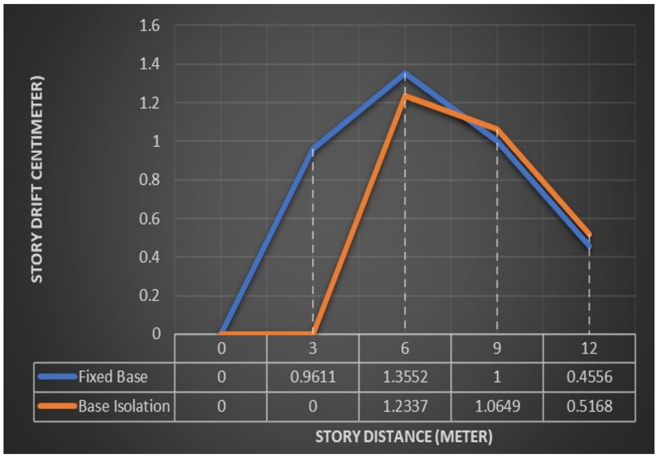


Fig.14. Distance vs. Story Drift for structure B

Compared to the fixed-base structure, which has failed floor levels, the base-isolated structure generated from structure B effectively passed all the floor levels. Also, story drift for buildings with a base isolation system is reduced. This result proved how the proposed elastomeric bearing reduces lateral displacements or deflections and damages brought on by seismic forces.

The average displacement per story level obtained from the seismic analysis for the fixed-base and base-isolated is illustrated in Tables 14 and the graphical representations is in Figure 15 for Structure A The results indicate that base isolation provides (2.1802) m at the roof level compared to a fixed-base (1.8951) m in the x-direction. Also, the ground level for the base isolation is (0.7756) m while (0.4496) m for the fixed-base structure. Also, the average displacement of the structure increases as the story height increases. At the x-direction of the ground floor, the average displacement of base-isolated structure increased by 72.51%. This result proves that base isolation structures are more flexible than fixed-base structures.

Table.14. Average Displacement Comparison Structure A

Story	Height (m)	Average Displacement (cm) X			
		Fixed-Base		Base-Isolated	
		Value	Status	Value	Status
Foundation Level	0	0.0000	Pass	0.0000	Pass
Ground Floor	3	0.4496	Pass	0.7756	Pass
2nd Floor	6	1.1087	Pass	1.3770	Pass
3rd Floor	9	1.6110	Pass	1.9049	Pass
Roof Level	12	1.8591	Pass	2.1802	Pass

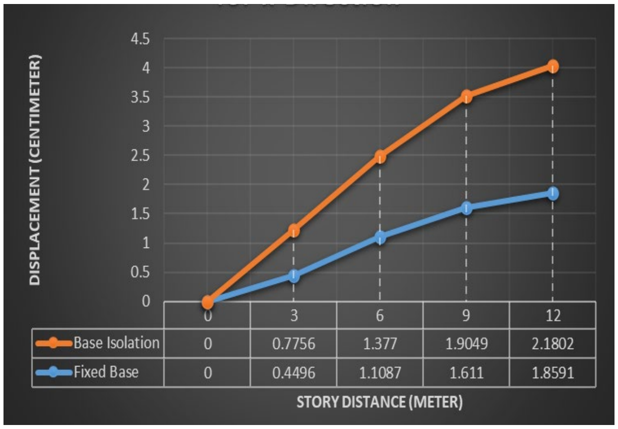


Fig.15. Story Distance vs. Story Displacement for Structure A

The average displacement per story level obtained from the seismic analysis for the fixed-base and base-isolated is illustrated in Tables 15 and the graphical representations is in Figures 16 for Structure B. Both proposed buildings continue to increase as story height increases. When there is ground movement, it is seen that base-isolated structures demonstrate significant flexibility. Comparatively to the fixed-base structure, which failed on the second-floor level, structure B successfully passed all the floor levels.

Table.15. Average Displacement Comparison Structure B

Story	Height (m)	Average Displacement (cm) X			
		Fixed-Base		Base-Isolated	
		Value	Status	Value	Status
Foundation Level	0	0.0000	Pass	0.0000	Pass
Ground Floor	3	0.9611	Pass	3.3307	Pass
2nd Floor	6	2.3163	Fail	4.5644	Pass
3rd Floor	9	3.3163	Pass	5.6293	Pass
Roof Level	12	3.7719	Pass	6.1416	Pass

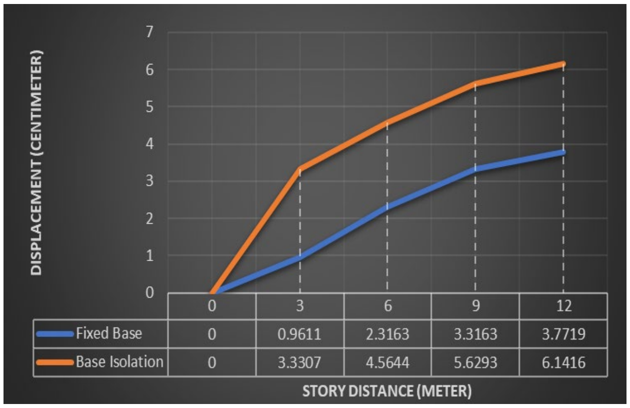


Fig.16. Story Distance vs. Story Displacement for Structure B

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Designing a building with base isolation is challenging due to the limited number of existing studies conducted in entire countries when analyzing the proposed system on the structure using the STAAD Pro design software.

A three-story structure is successfully designed with a base isolation system with the help of advisors. Apart from adding a base isolation system (elastomeric rubber bearing) between the superstructure and the foundation, there were no significant visual differences between the proposed building and other academic buildings on the DHVSU Lubao Campus. The design of the building helps reduce the dynamic response of the building that can withstand earthquakes.

The seismic base isolation method has proven to be an effective earthquake-resistant design method. In this research study, an elastomeric rubber bearing base isolator and a conventional building have been proposed thoroughly. The seismic response of each structure was performed using a dynamic analysis of a three-story academic school building. A comparison of different parameters such as dynamic analysis, modal analysis, base shear, story drift, and displacement is conducted.

This study achieved its main objective of evaluating the efficiency of the proposed base isolation system and minimizing the impact of potential earthquake damage. The results of the base-isolated structure have effectively passed all the floor levels compared to the fixed-base structure that has failed floor levels. Moreover, it can be observed that story drift for building with a base isolation system reduces the drift. These results prove that the proposed elastomeric bearing lessens lateral displacements or deflections and damages due to seismic forces. Their average displacements demonstrate that base isolation structures are more flexible than structures with a fixed base. Both the x and z directions decrease the expected maximum lateral forces at the base of the building caused by the earthquake ground movements.

Designing a building with a base isolation system is possible to construct here in the Philippines, following its specification and building codes. This study investigated and demonstrated the safety of the structural members considering the necessary wind load, seismic load, dead load, and live load for the Philippines. When an earthquake occurs, the study concludes that the building will be safe, economical, and less damaged compared to the conventional fixed-base structure after many years.

4.2 Recommendations

In the past few years, some related studies about Base Isolation Technique have proven the efficiency of methods in different ways. In line with the result of this paper, the main goal was successfully achieved. The analysis of dynamic features of the proposed three-story building has proved the effectiveness of the results of the study. Although the results were successful, this study implies that other factors are needed to demonstrate the effectiveness fully.

When minimizing the effect of seismic forces, isolators are proven to be one of the best courses of action as a seismic response for the structures. Aside from elastomeric bearing, it is suggested to use different materials and dimensions of isolators to identify the most efficient and most suited isolator for a three-story building. For additional research, try analyzing a high rise or an irregularly-shaped structure to explore further the efficiency of the proposed technique. The cost analysis for the Base Isolation Method and the materials used, and the technique is also encouraged for future studies to determine if the method would be economical and cost-effective against the conventional way. Choosing where and when to use the technique mentioned above is also an excellent objective for future investigation of the topic as it would generate a basis and criteria for the Base Isolation Method. These suggestions and recommendations are for the betterment of the study. They would drastically improve how future structures would be built to resist unforeseeable destructive events like earthquakes.

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