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Research Paper

Behavior of Reinforced Concrete Portal Structure With and Without Brick Wall

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Abstract

Indonesia is an area prone to earthquakes. This has a negative impact on building damage and increases the injury/death rate. Buildings have generally been designed to be earthquake-resistant. However, in planning does not consider the presence of a filler wall in the form of a brick wall. This research takes a study of existing buildings in the form of portals consisting of three floors. The portal was analyzed by pushover analysis method and modeled with no walls and with brick walls using seismostruct software. The results showed that brick walls have a significant influence on the behavior of structures, especially in increasing load-bearing capacity.

Keywords: Earthquake, Portal with Wall Brick, Sesimostruct, Pushover Analysis, Structural Behaviour

INTRODUCTION

Geological conditions cause Indonesia to experience a high level of vulnerability to earthquakes. Earthquakes that occur in an area can have adverse consequences causing casualties and damage to buildings as happened in Aceh and West Sumatra (BMKG, 2019). The main causes of post-earthquake building damage are the design of structures that do not meet the requirements of earthquake-resistant buildings, inadequate regulations, and do not apply the concept of earthquake-resistant buildings. Therefore, multi-storey buildings need to be designed according to applicable regulations and follow the concept of earthquake-resistant buildings (Tamara, 2011).

Brick walls are commonly used all over the world for reinforced concrete buildings. These red brick walls are used for internal and external separation and serve as thermal and acoustic insulation. As a result of earthquakes, these walls receive lateral forces of planes received through the portal elements of the structure. Over the past few decades, many studies have been conducted to study the effect of brick infill walls on the response of steel portals and reinforced concrete.

Reinforced concrete buildings are usually designed without considering the influence of brick walls. In construction practice, reinforced concrete portals are often installed brick walls for architectural purposes. Brick wall panels are considered a nonstructural system and are often overlooked in the seismic response analysis of Wijaya et al., (2020) buildings. However, previous research has shown that brick wall panels alter the response of structures exposed to lateral loads (Korkmaz et al., 2007; Pujol & Fick, 2010). The behavior of brick walls to the seismic response of the structure depends on the structural configuration and earthquake load. In addition, brick walls can cause irregularities in the vertical direction in the twisting behavior of buildings and in soft-story mechanisms that can increase the risk of structural collapse (Rajeev & Tesfamariam, 2012). Therefore, studies both experimentally and numerically to understand the effects of brick walls on the seismic performance of structures have been conducted by several previous researchers (Centeno, 2007; Dolšek &; Fajfar, 2008; Fiore et al, 2012; Mondal &; Tesfamariam, 2014; Uva et al,

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2012).

Therefore, research to study the behavior of reinforced concrete structures due to the use of brick walls needs to be carried out. Analysis of the behavior of structures is carried out by comparing the behavior of reinforced concrete portals without the use of brick walls and portals that use brick walls. The analysis method used is pushover analysis using SeismoStruct software.

LITERATURE REVIEW

Earthquakes

Based on the Ministry of Energy and Mineral Resources in 2015, an earthquake is an event of shaking the earth caused by collisions between earth plates, active faults of volcanic activity or rock collapse. The movement of the earth's plates can be seen in Figure 1 Eurasian Pl

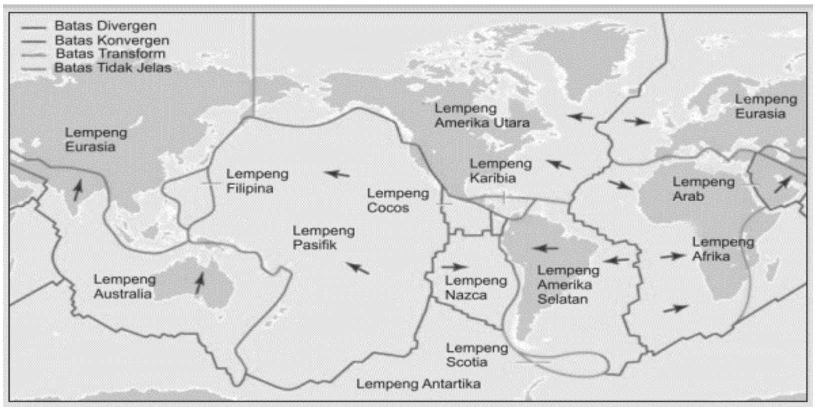

Figure 1. The direction of movement of the Current Plate follows the direction of the arrow (ESDM, 2015)

The cause of the movement of these plates (Figure 1.) according to scientists is due to convection currents (heat transfer) that occur in the earth's envelope, the temperature of the envelope is very hot causing parts of the envelope to flow like a thin liquid. The area where the plates meet is called the plate boundary. There are 3 types of plate movement, namely the movement of plates colliding with each other (convergent boundaries), moving away from each other (divergent boundaries) and sliding each other sideways (transform boundaries).

Structural Analysis

Pushover Analysis

Pushover analysis is a non-linear analysis that can replace dynamic-elastic analysis of structures against earthquakes. Loading and deflection of the structure obtained in pushover analysis based on initial conditions until the final condition of the structure is structural failure (Datta, 2010).

Brick Wall Modelling

Modeling techniques carried out on brick walls can be done in three ways, namely micro-modelling, meso-modelling and macro-modeling (Bouarroudj & Boudaoud, 2022). These three techniques differ in complexity, computational time, and accuracy.

SeismoStruct

Displacement behavior due to static and dynamic loading can be predicted using seismostruct software based on material elasticity and nonlinear geometry (Figure 2.).

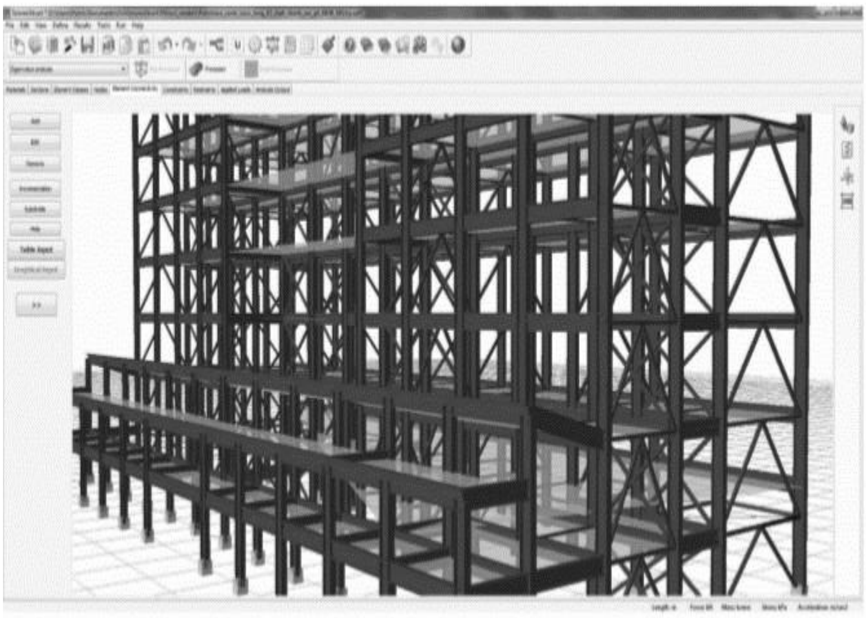

Figure 2. Seismostruct Software (Seismostruct, 2018)

RESEARCH METHODOLOGY

This research began by modeling the portal structure of a shophouse building consisting of three floors. This shophouse is an existing building. In the planning and implementation of the construction of this shophouse has been designed according to earthquake-resistant building regulations with SNI 1726:2019 for earthquakes and in accordance with SNI SNI 2847:2019 for concrete concrete regulations. However, in the planning of this building do not consider and take into account the filler walls. The modeling of this structure is modeled according to drawing data (dimensions of beams, columns, and other supporting data) using seismostruct software. Then the building structure is analyzed using the pushover analysis method.

Brick Wall

Panel elements or quadrilateral elements with four nodal points were originally developed and programmed by Crisafulli (1997) and implemented in Seismostruct by Blandon (2005), to model the nonlinear response of infill wall panels in portal building structures. Each panel is represented by six strut elements. Each diagonal direction features two parallel struts to withstand axial loads at two opposite diagonal angles and a third to bear the sliding force from top to bottom of the wall panel. The latter strut only works across diagonals that receive compressive forces and depends on the deformation of the panel. The behavior of strut materials due to axial loads uses a strut hysteresis curve model for walls, while model materials due to shear forces use a special bilinear hysteresis curve. In addition to this observable in Figure 5, four internal nodals are used to account for the actual point of contact between the portal element and the filler wall panel (i.e. to take into account the width and height of each column and beam, while four dummy nodals are used to account for the length of contact between the portal element and the filler wall panel. All these inner styles are transformed into the four exterior nodals where the wall elements are connected with the portal elements.

Analysis of Existing Structure

The data inputted is in the form of the size and dimensions of the structure, as well as details of repeating structural elements such as beams and columns. Structure data is inputted into the Seismostruct Software. The initial data is obtained from structural drawings in Autocad as shown in Figures 3., Figures 4. and Figures 5. The building consists of 3 floors with a total span of 2 spans in the x direction and 2 spans in the y direction and a total building height of 11,070 meters. For tabulation of the dimensions of beams and columns can be seen in Table 1. and Table 2.

Table 1. Table of Dimensions of 2nd, 3rd, and Roof Floor Beams

Beam Type	**Rebar**						
	Dimension	**End**		**Mid**		**Stirrup (End)**	**Stirrup (Mid)**
	(mm)	**Top Rebar**	**Bottom Rebar**	**Top Rebar**	**Bottom Rebar**		
2nd and 3th Floor							
B24	200 x 400	4 D 13	3 D 13	2 D 13	4 D 13	D 8 - 150	D 8 - 200
B24A	250 x 400	8 D 13	4 D 13	3 D 13	4 D 13	D 8 - 150	D 8 - 200
B34 B	300 x 450	6 D 16	3 D 16	3 D 16	6 D 16	D 10 - 100	D 10 - 125
Roof							
B12A	150 x 200	2 D 13	2 D 13	2 D 13	2 D 13	D 8 - 150	D 8 - 200
B23	200 x 300	3 D 13	2 D 13	2 D 13	3 D 13	D 8 - 150	D 8 - 200
B24	200 x 400	5 D 13	3 D 13	2 D 13	4 D 13	D 8 - 150	D 8 - 200
B24Ax	250 x 400	4 D13	3 D 13	2 D 13	3 D 13	D 8 - 150	D 8 - 200
2nd, 3th Floor, and Roof							
B24Ax (*Cantilever*)	250 x 400	5 D 13	3 D 13	5 D 13	3 D 13	D 8 - 150	D 8 - 200
B24x	200 x 400	4 D 13	3 D 13	3 D 13	3 D 13	D 8 - 150	D 8 - 200

Table 2. Column Dimension

Column Type	**Dimension (mm)**	**Reinforcement**				
		Dia.	End		Mid	
		(mm)	*HOOP*	*CROSSTIES*	*HOOP*	*CROSSTIES*
K12A	150 x 200	4 D 13	D 8 - 150	D 8 - 150	D 8 - 150	D 8 - 150
K34	300 x 400	10 D 16	D 8 - 150	D 8 - 150	D 8 - 150	D 8 - 150
K34x	300 x 400	8 D 16	D 8 - 150	D 8 - 150	D 8 - 150	D 8 - 150
K24A	250 x 400	8 D 16	D 8 - 150	D 8 - 150	D 8 - 150	D 8 - 150
K24Ax	250 x 400	6 D 16	D 8 - 150	D 8 - 150	D 8 - 150	D 8 - 150

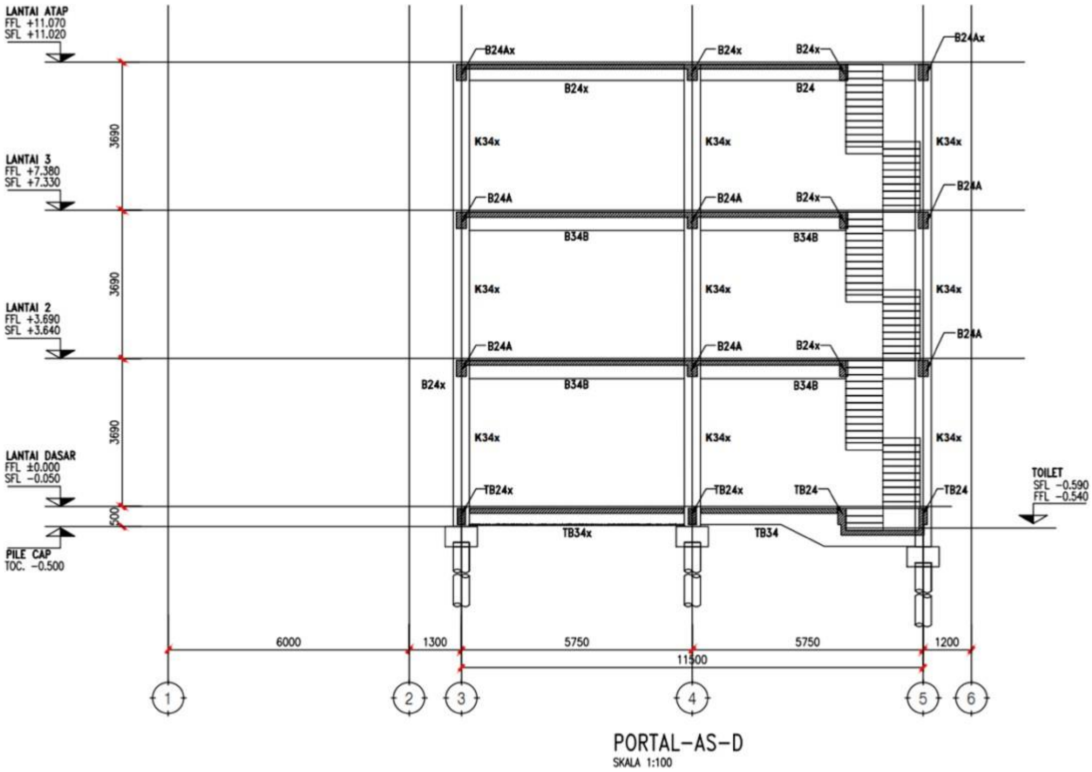

Figure 3. Portal AS D on Autocad drawing

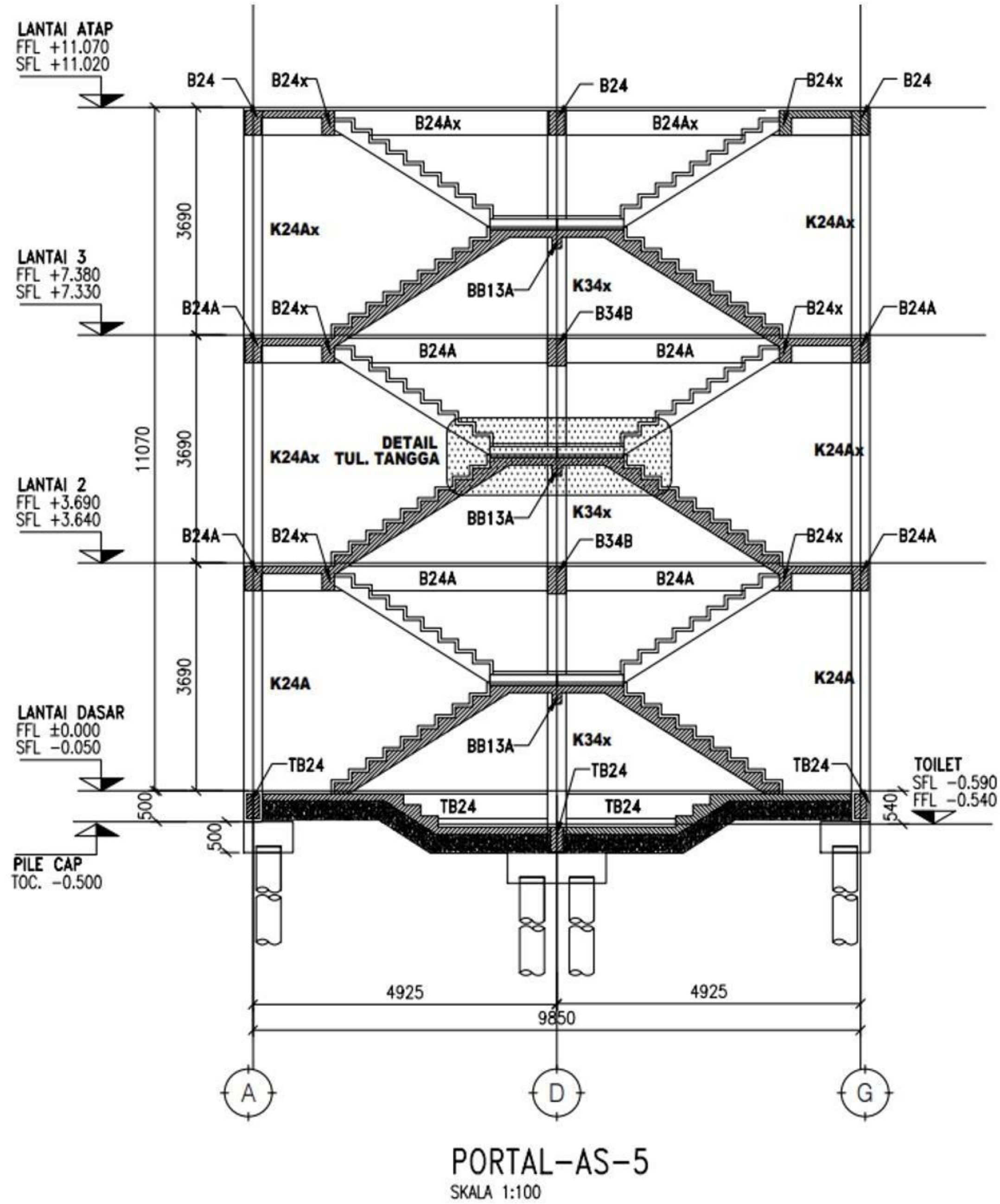

Figure 4. Portal AS 5 on Autocad drawing

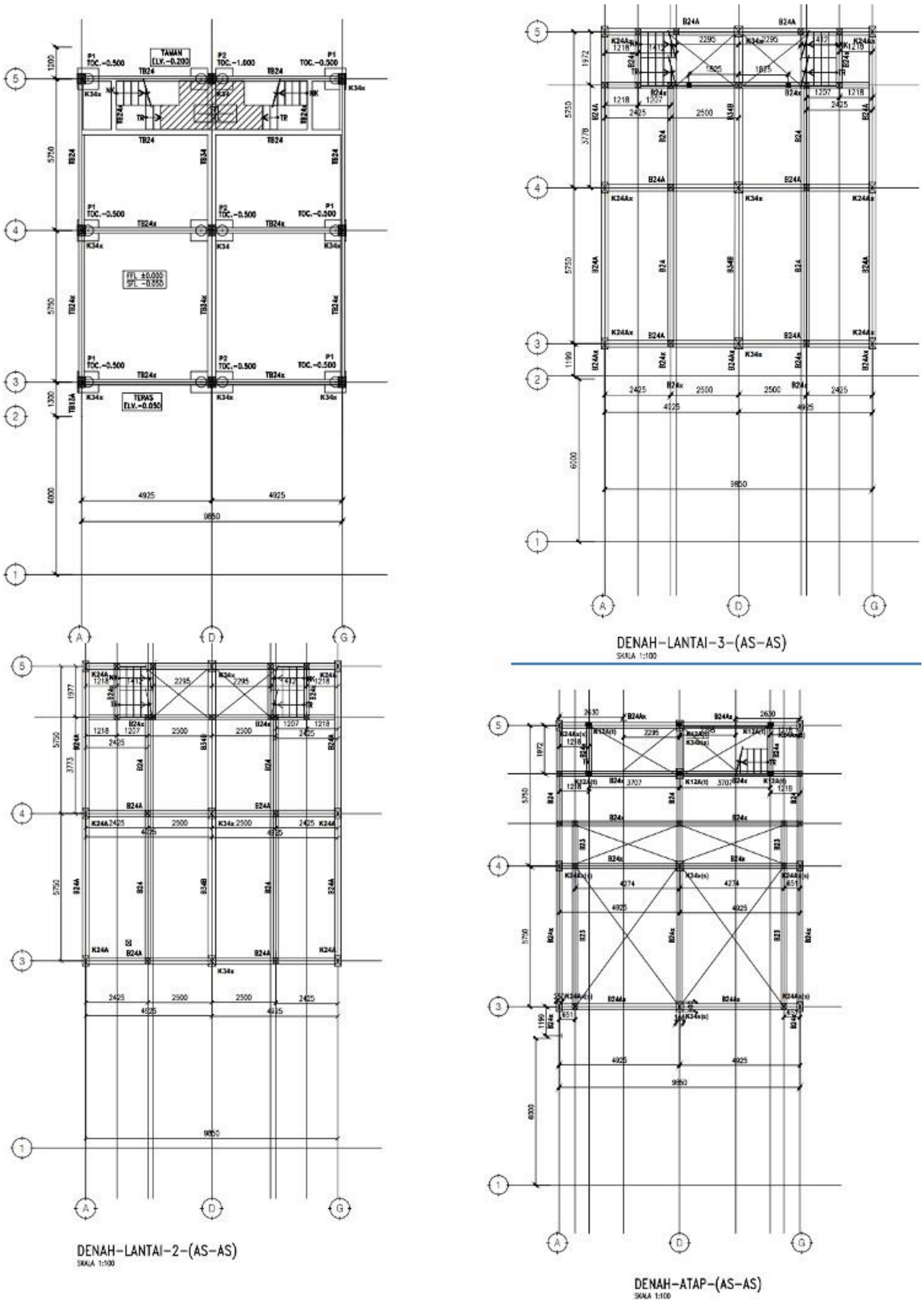

Figure 5. Foundation plan/Ground Floor, 2nd Floor, 3rd Floor and Roof on Autocad drawing

FINDINGS AND DISCUSSION

Research Design

In this study, the modeling of the building structure used Seismostruct Software v2023 Release-2 Build-25. The model of the shophouse building structure consists of 2 types of models, namely model 1 open portal (without walls) and model 2 portals with walls. The model is made in 3D which can be seen in Figures 6., 7, 8 and 9.

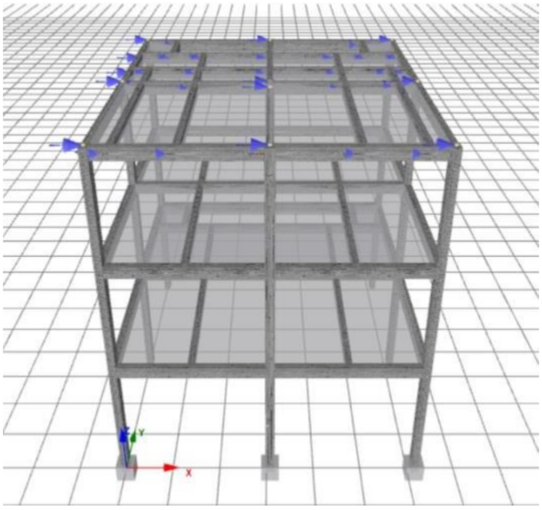

Figure 6. 3D modeling of shophouse building structure without walls (model 1) by using Seismostruct Software

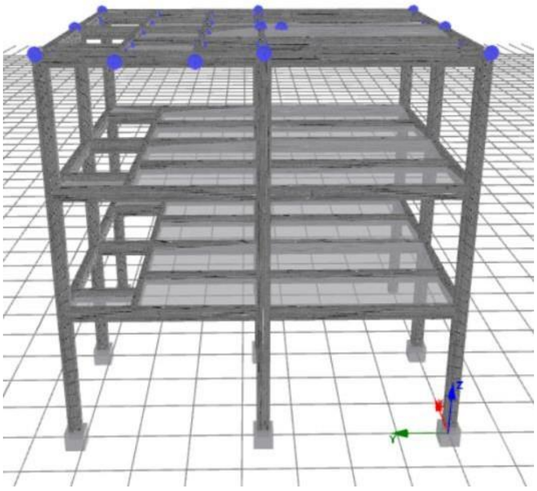

Figure 7. 3D modeling of shophouse building structure without walls (model 1) using Seismostruct Software (Side View)

In Figures 9 and 10 it can be seen that this portal consists of 3 floors and 2 spans. With variable column and beam dimensions that can be seen in Tables 1 and 2. In this Seismostruct Software portal is analyzed using Static time-history analysis.

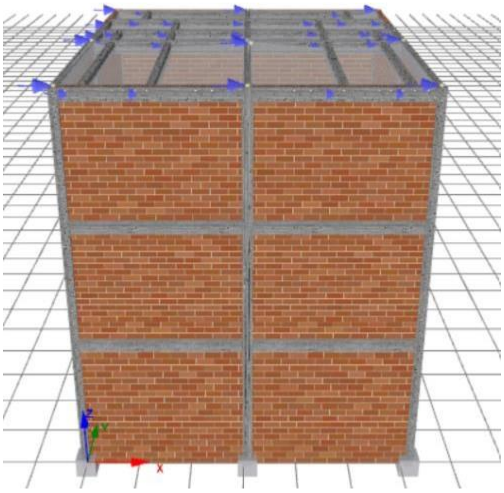

Figure 8. 3D modeling of shophouse building structure with walls (model 2) using Seismostruct Software (Front View)

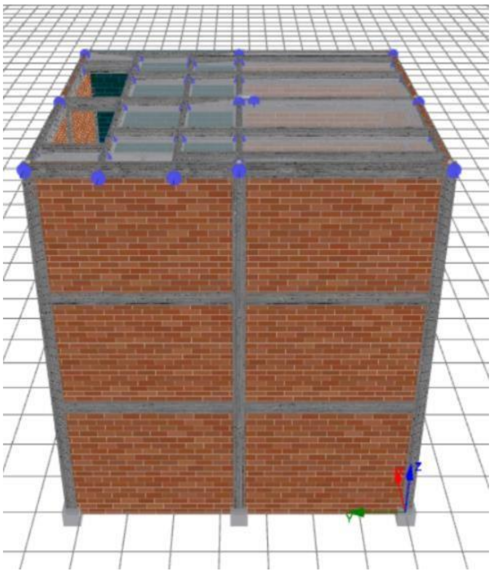

Figure 9. 3D modeling of shophouse building structure with walls (model 2) using Seismostruct Software (Side View)

In Figures 6. and 7. it can be seen that the portal has a similar shape to Figures 8. and 9. but the difference is in the addition of a wall full of beams and columns on the outer side.

Portal analysis of models 1 and 2 will be observed in the X direction and the Y direction. The drift ratio or structure deviation ratio used in this study was 0.20%, 0.25%, 0.35%, 0.50%, 0.75%, 1%, 1.40%, 1.75%, 2.20%, 2.75%, 3.50%, 4.25%, 5%, 5.75%, 6.5%, and 7.25%.

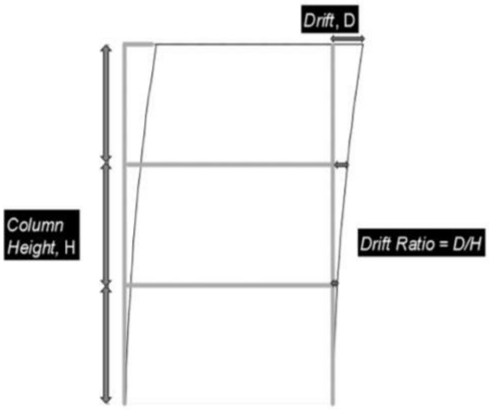

Figure 10. *Drift Ratio*

Displacement is obtained from the multiplication of this drift ratio with column height which can be seen in Figure 10. Then displacement is obtained as in Table 3.

Table 3. Drift Ratio and Displacement

No	*Drift Ratio*	*Displacement*
1	0.20%	7.38
2	0.25%	9.225
3	0.35%	12.915
4	0.50%	18.45
5	0.75%	27.675
6	1.00%	36.9
7	1.40%	51.66
8	1.75%	64.575
9	2.20%	81.18
10	2.75%	101.475
11	3.50%	129.15
12	4.25%	156.825
13	5.00%	184.5
14	5.75%	212.175
15	6.50%	239.85
16	7.25%	267.525

In this study, the earthquake loading on the portal underwent several cycles of large lateral force reversals. This cycle continues until the portal structure melts or collapses. Through Seismostruct Software, these portals analyzed the interaction between filler walls and reinforced concrete structures in receiving cyclic loads. Both models of these portals are loaded in the X and Y directions.

Capacity Curve Results

Open Portal (Without Wall) Capacity Curve

a. Open Portal (Without Wall) X Direction Capacity Curve

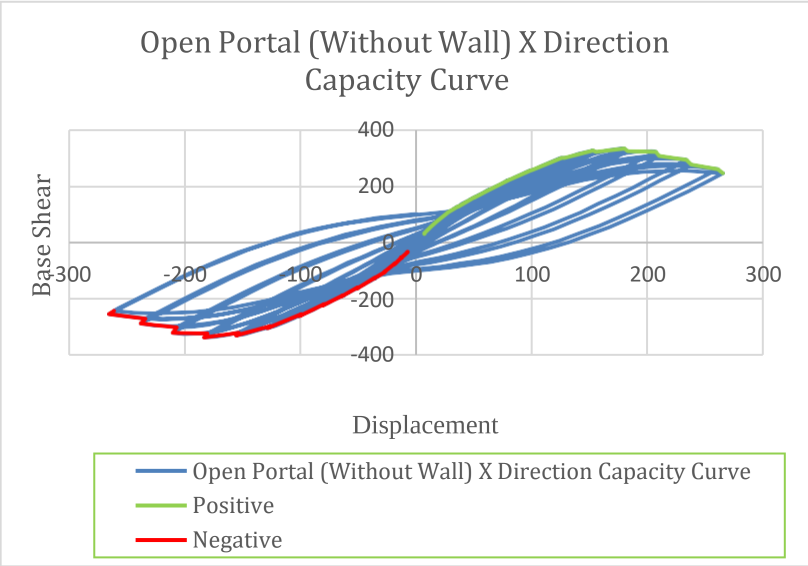

Figure 11. Capacity curve of open portal (without wall) X direction

Based on the observations in Figure 11. of the Capacity Curve of the Open Portal (Without Wall) in Direction X, a maximum lateral load-bearing capacity of 245,829 kN was obtained at a maximum displacement of 265,385 mm and a drift ratio of 7.25%. And the negative lateral load-bearing capacity of 243,363 kN at a negative displacement of 261,104 mm and a drift ratio of 7.25%.

b. Open **Portal Capacity Curve (Without Wall) Direction Y**

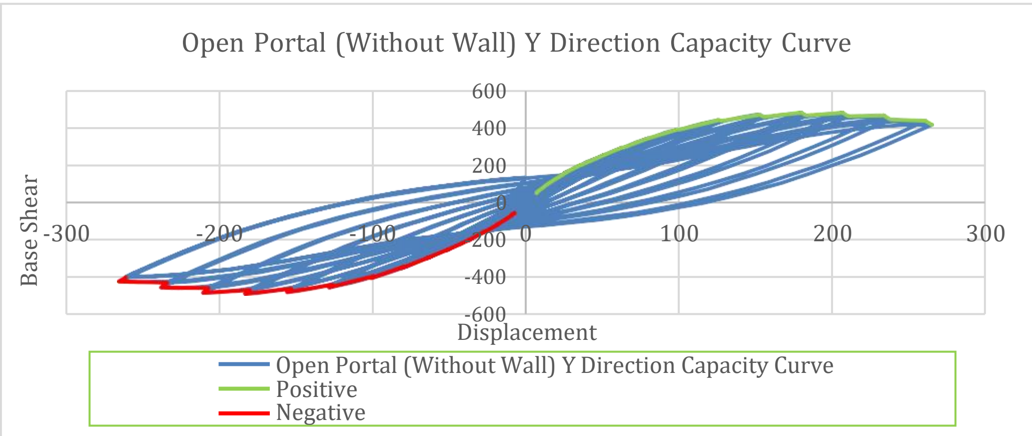

Figure 12. Capacity curve of open portal (without wall) Y direction

Based on the observations in Figure 12. of the Capacity Curve of the Open Portal (Without Wall) in the Y Direction, the maximum lateral load-bearing capacity of 419,619 kN at a maximum displacement (displacement) of 265,385 mm and a drift ratio of 7.25% were obtained. And the negative lateral load-bearing capacity is 400.21 kN at a negative displacement of 261.104 mm and a drift ratio of 7.25%.

Portal Capacity Curve with Wall
a. Portal Capacity Curve with X-Direction Wall

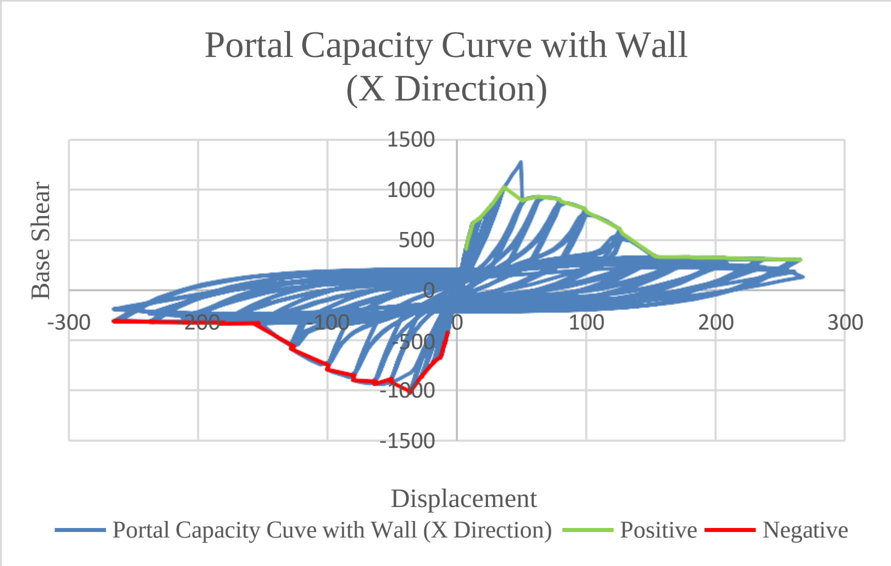

Figure 13. Portal with Wall Capacity Curve (X Direction)

Based on the observations in Figure 13. of the Capacity Curve of the Portal with Wall in the X Direction, the maximum lateral load-bearing capacity of 303,932 kN at maximum displacement of displacement is 265,385 mm and the drift ratio is 7.25%. And the negative lateral load-bearing capacity of 304,079 kN at a negative displacement of 261,104 mm and a drift ratio of 7.25%.
(b) Portal Capacity Curve with Y-Direction Wall

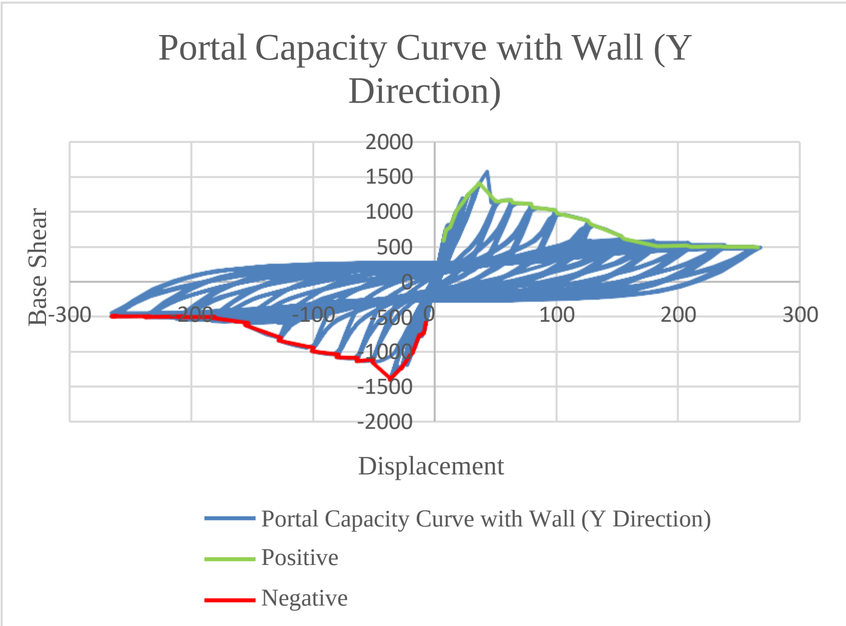

Figure 14. Portal Capacity Curve with Y-Direction Wall

Based on the observations in Figure 14. of the Capacity Curve of the Portal with Wall in the Y Direction, a maximum lateral load-bearing capacity of 489,314 kN was obtained at a maximum displacement of 265,385 mm and a drift ratio of 7.25%. And the negative lateral load-bearing capacity of 487,559 kN at a negative displacement of 261,104 mm and a drift ratio of 7.25%.

CONCLUSIONS

1. The brick filling wall on the portal can significantly increase the load-bearing capacity for loading in both X and Y directions.
   a. In X-direction loading, portals with brick walls increase maximum and minimum load-bearing capacity by 206.389% and 201.899% respectively with values of 1023.9 kN and -1019.2 kN at the same displacement of 265.385 mm and -265.385 mm against open portals (without walls).
   b. In the Y direction loading, portals with brick walls increase maximum and minimum load-bearing capacity respectively by 191,005% and 186,550% with values of 1406.5 kN and -1399.8 kN at the same displacement of 265,385 mm and -265,385 mm against open portals (without walls).
2. The filler wall can change the distribution of damage throughout the structure.

FURTHER RESEARCH

1. Perform portal modeling that studies the influence of openings (size, position and type of openings) use seimostruct software or experimental study.
2. Modeling with different types of filler walls such as adobe walls and precast walls.

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