GSJ: Volume 11, Issue 10, October 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

# STUDY ON PERFORMANCE OF MASONRY BUILDING AND THEIR IMPROVEMENT TECHNIQUES

Mahesh Devkota, Dipesh D.C

*Mahesh Devkota is currently pursuing master's degree program in structural engineering in Graduate School of Engineering, Mid-West University, Nepal,*
*Dipesh D.C is currently working as Asst.Prof at Central Department of Civil Engineering, Mid-West University, Nepal*

## KeyWords
Push over Analysis, Idealized Curve, Masonry building, Target Displacement, Yield Base Shear.

## ABSTRACT
A large number of older buildings are constructed of stone/brick masonry in Nepal without considering earthquake resistance design. Thus, many masonry buildings were significantly impacted by the Gurkha earthquake 2015. During earthquakes, different failure patterns emerge in masonry buildings. Elements like opening sizes and Wall lengths seem to influence failure, but their exact relationships aren't clear. This study aims to unrevealed the roles and connections of these components in lessening masonry building responses. This study is focused in comprehensively examining the seismic response of these constructions and explore strategies for reinforcement. This study involved the utilization of 12 distinct models. These models featured wall thicknesses of 40 cm (with lengths of 4.2 m, 5 m, and 7.2 m) and a wall thickness of 20 cm with a length of 4.2 m. Furthermore, the models encompassed variations in the presence of openings, specifically 0%, 11.57%, and 23.15%. The pushover analysis was performed all the models using SeismoStruct 2023. The study concludes that buildings with fewer openings perform better, showing higher base shear and less deformation. As damage increases, less open structures approach near collapse with significant deformation. Short walls collapse due to high base shear, while longer walls excel in base shear up to the yield point, attributed to their flexibility causing increased deformation until damage limitation. Overall, shorter walls outperform longer ones from significant damage to collapse, displaying greater deformation upon Collapse.

## 1. INTRODUCTION

NEPAL is land lock country nestled in the foothill of the Hima-layas. Topographically, Nepal is divided into three distinct ecological regions. These are the Mountains, Hills, and Terai. According to the recent population census of Nepal in 2078, 6.08 percent of the total population lives in Mountain, 40.31 percent of the total population lives in Hills and 53.61 percent of the total population people's lives in Terai [1]. Population cen-sus also shows that 30.7 percent of residential buildings are constructed using mud mortar stone/brick masonry anda-mong them, 83.1 percent are in Karnali Province. Due to the lack of transportation , and skilled manpower facilities con-struction of buildings using modern construction materials and technology becomes costlier and the economic condition of people in rural areas cannot afford expensive technology.

The entire territory of Nepal lies in a high seismic hazard zone. The country's high seismicity is related to the movement of tectonic plates along the Himalayas which has caused sev-eral active faults. From previous earthquakes, it is seen that unreinforced masonry load-bearing building seen more open-ings, window, and door openings at appropriate locations, etc. observed less damage. In this study effect on the perfor-mance of the building at lateral load due to opening size and length of wall are taken into consideration. Wall length, open-ing size are taken as study parameters. Masonry walls are strong in compression and weak in flexure. Earthquakes can affect the Masonry Buildings due to their vulnerability to seismic forces Some effect of the Failure of masonry building due to the Seismic action are Connection Failure, Damage at to Joint ,In Plane failure, Out of plane failure, due to opening the wall. These various modes of failure shows the vulnerabilities of masonry buildings during seismic event. Implementing different techniques to improve their seismic performance and reduce the risk of Earthquake.

## 2. LITERATURE REVIEW

Prasanna and Santhi studied the seismic eval-uation of residential buildings with masonry walls using Non-linear Pushover Analysis via Etabs soft-ware. Evaluated the seismic resistance of brick ma-sonry walls with openings and diagonal frames. Highlighted the effectiveness of the diagonal strut approach in simulating the seismic response of RC frames with masonry infill.[4]

Fulvio and Augenti ivestigated the seismic capacity of irregular unreinforced masonry walls with openings. Utilized Static Pushover Analysis and experimental validation, the study focused on four two-way solid brick masonry walls. Aimed to de-termine the potential reduction in seismic capacity when openings are closed or modified [2].

Zhen and Crewe (2020) studied the Effect of size and position of opening on in-plane capacity of unreinforced masonry walls using discrete ele-ment modeling and experimental validation. Con-cluded that increasing opening percentage reduces in-plane capacity and often changes failure mech-anisms, influenced by opening size, location, and shape. The relationship between lateral capacity and opening percentage varied depending on the analysis method used.[9]

## 3. STATEMENT OF PROBLEM

From the population census of Nepal, 2078 about 30.7 per-cent of residential buildings in Nepal are constructed using mud mortar stone/brick masonry. Past earthquake data show that masonry building is more vulnerable. Different failure patterns are observed in masonry buildings during 2015 Gurkha earthquakes. Some elements in masonry buildings like opening sizes, and lengths are observed to play a role to minimize failure in masonry buildings but the actual rela-tions of these components are not known. This study is fo-cused to identify their individual role and interrelationship to reduce response in masonry building

## 4. OBJECTIVE OF THE STUDY

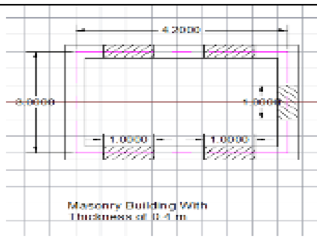
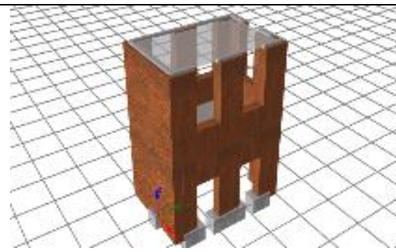
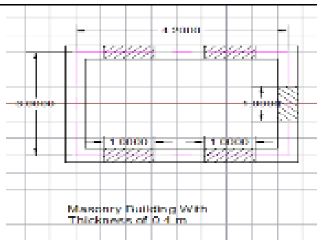
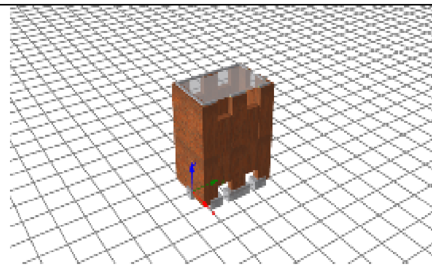
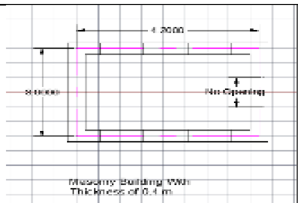
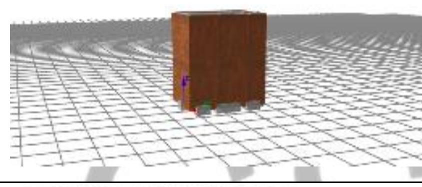
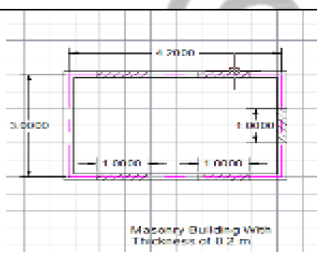
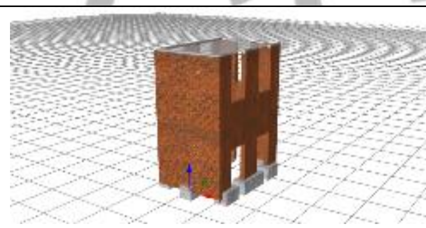
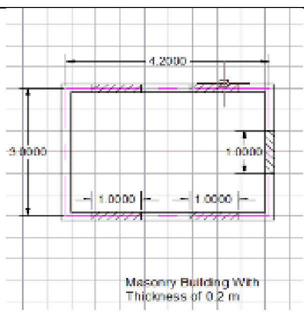
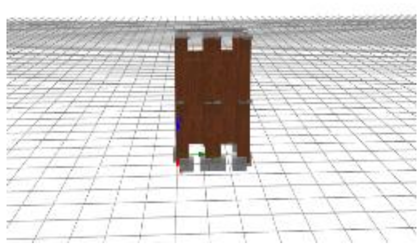
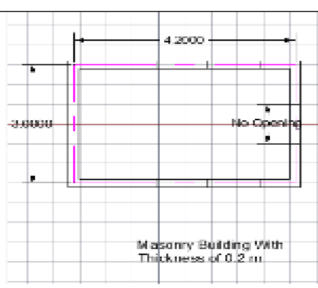
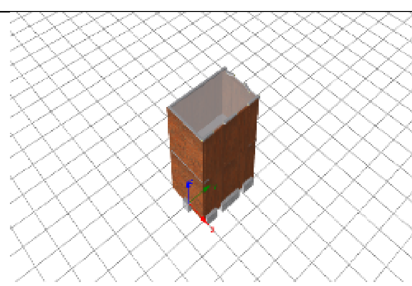


The main objective of the study is to evaluate the seismic be-havior of masonry buildings and strengthen techniques.

## 5. DIMENSIONS AND MODELS

Numerical analysis of the masonry building were performed using Seismostruct2023 software Computer program which is a Finite Element package capable of predicting the large dis-placement behavior of space frames under static or dynamic loading, taking into account both geometric nonlinearities and material inelasticity. In this study to predict the dis-placement , Stress level, Formation of Hinge point of Masonry building.
The properties of Masonry Wall is defined as ,
Mean Compressive strength – fc =3500 KPa.
Mean Tensile strength – ft = 150 KPa.
Modulus of Elasticity – Ec = 1.05E+07 KPa.
Poisson Ratio =0.02
Strain at peak stress – εc=0.002.
Specific weight = 24 kN/m3.
Applied Permanent loads in masonry = -10 KN
Applied Incremental loads in masonry = 5KN
Length of Wall 'L', Thickness 't' and Opening is 'O' For Sam-ple modeling of Masonry buildings are follows,

6. DIMENSIONS AND MODELS

| SN | Plan | 3D | Remarks |
|---|---|---|---|
| 1 |  |  | L= 4.2m , t= 40 Cm & O= 23.15 % |
| 2 |  |  | L=4.2m , t=40 Cm & O= 11.57 % |
| 3 |  |  | L=4.2m , t=40 Cm & O= 0 % |
| 4 |  |  | L=4.2m , t=20 Cm & O= 23.15 % |
| 5 |  |  | L=4.2m , t=20 Cm & O= 11.57 % |
| 6 |  |  | L=4.2m , t=20 Cm & O= 0 % |

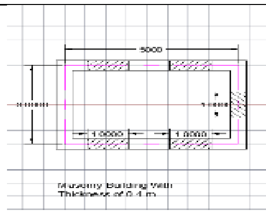
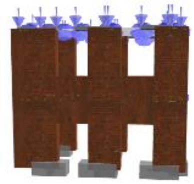
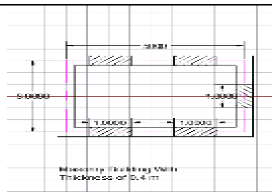
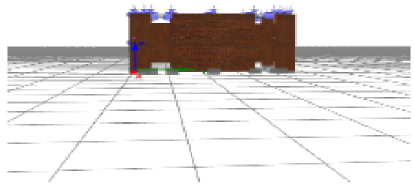
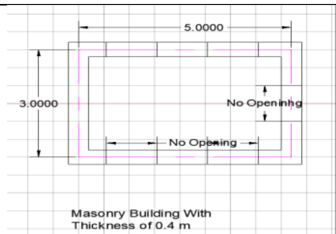
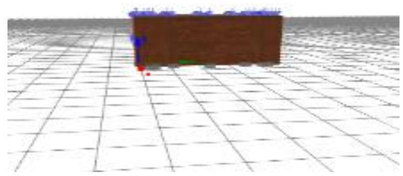
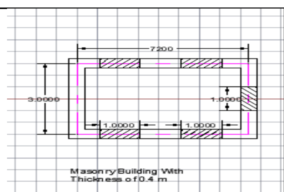
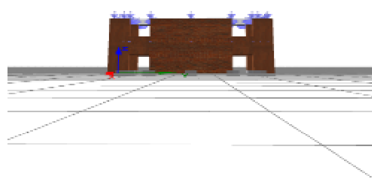
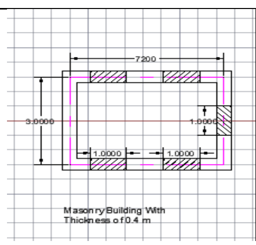
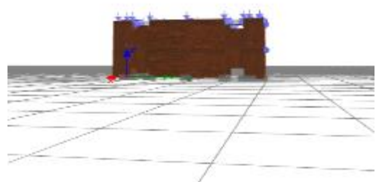
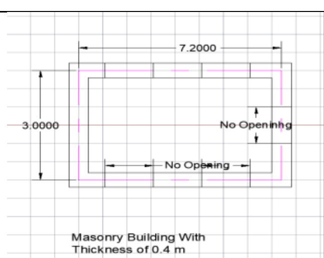
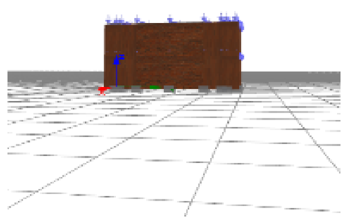
| | | | |
|---|---|---|---|
| 7 |  |  | L= 5.0 m , t=40 Cm & O= 23.15 % |
| 8 |  |  | L= 5.0 m , t= 40 Cm & O= 11.57 % |
| 9 |  |  | L= 5.0 m , t=40 Cm & O= 0 % |
| 10 |  |  | L= 7.2 m , t=40 Cm & O= 23.15 % |
| 11 |  |  | L= 7.2 m , t=40 Cm & O= 11.57 % |
| 12 |  |  | L= 7.2 m , t=40 Cm & O= 0 % |

*Figure 1. Building modeling*

## 7. DATA ANALYSIS AND MODELING PROCEDURES

For Pushover analysis is used to evaluate the seismic capacity of structures and appears in several guidelines for Seismic design. It is useful for performance based design of building that rely on ductility or redundancies to resist Earthquake Force

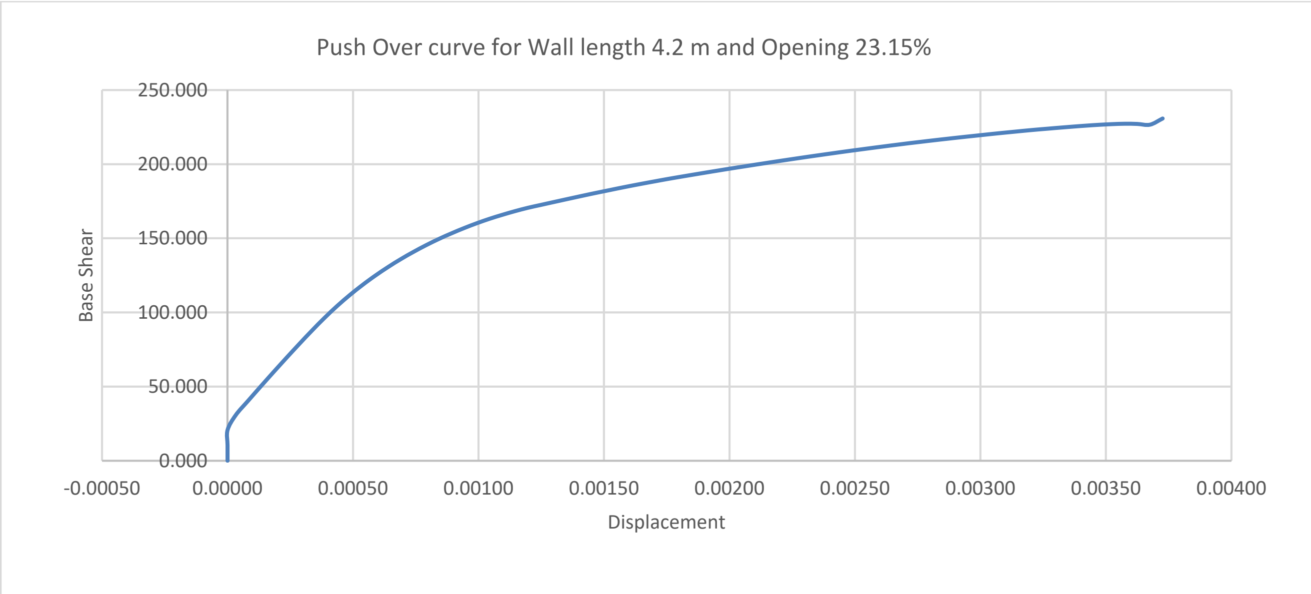



*Figure 2 Pushover Analysis*



For performance Based Evaluation of the building analysis, estimate the inelastic response for the building due to earth-quakes.

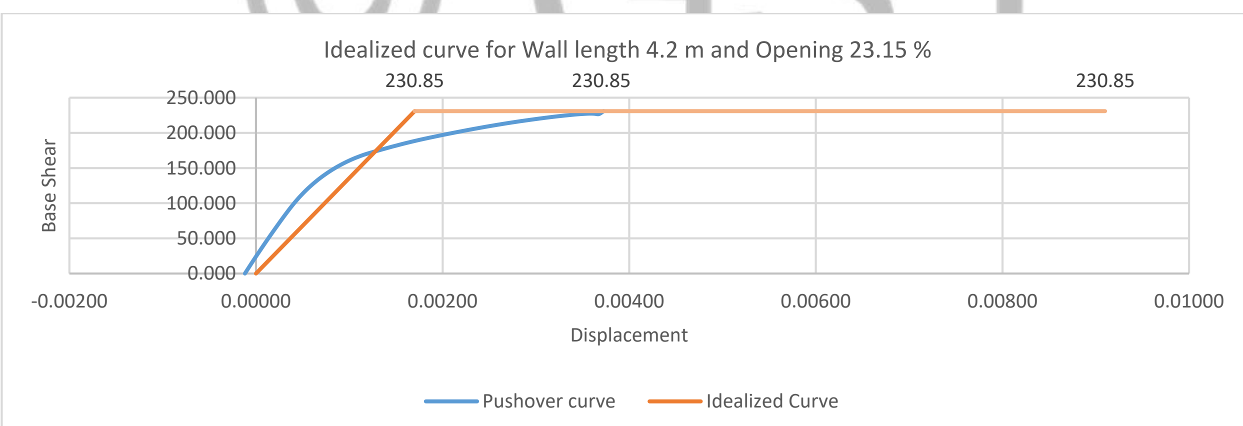



*Figure 3 Idealized Curve*

## 8. RESULTS

8.1. Performance Comparison Variation on Opening Percentage .

A. Pushover Curve

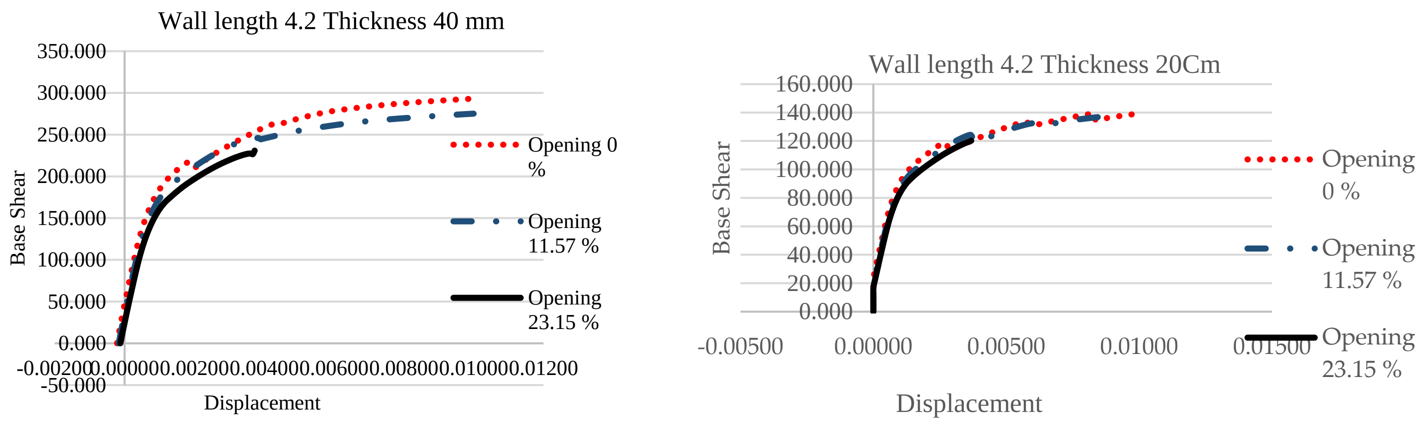



*Figure 4 (a) Pushover Curve for 4m length 40 cm Thickness and Variation of Opening, (b) Pushover Curve for 4m length 20 cm Thickness and Variation of Opening.*

From above Observation (figure 4a)Displacement and Base Shear is to be found .It is seen that maximum displacement (0.01m) is occurred Base shear (293.17KN) when the Opening of Building is to be zero and minimum displacement (0.0037m) is to be noted in Base shear (230.85KN) when the opening Size is 23.15%.

From the above graph ,( figure 4b) Displacement and Base Shear is to be found .It is seen that maximum displacement (0.0083m) is occurred in Base shear (139.31 KN) when the Opening of Building is to be zero and minimum displacement (0.0028 m) is to be noted in Base shear (135.59 KN) when the opening Size is 23.15%.

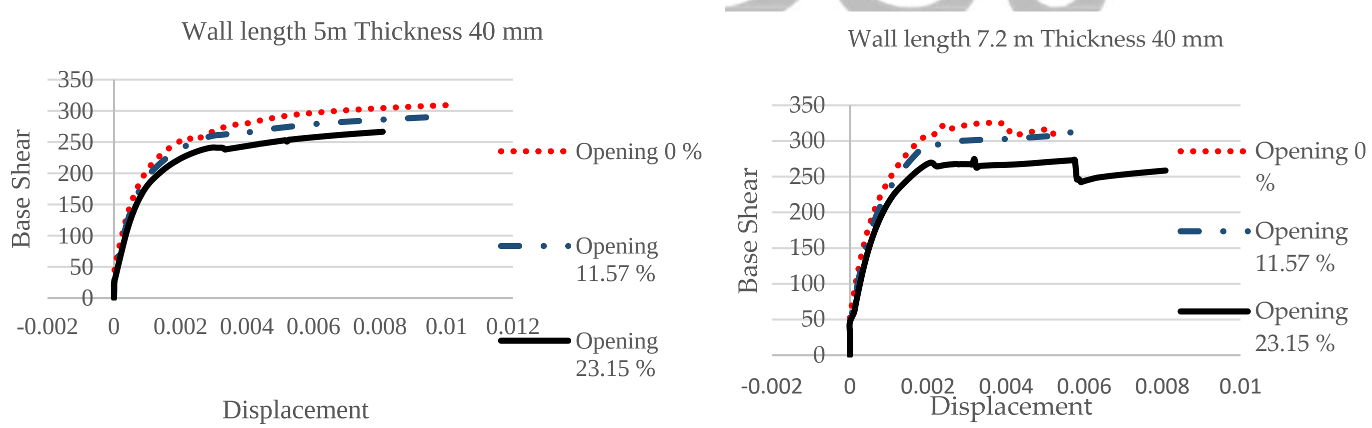
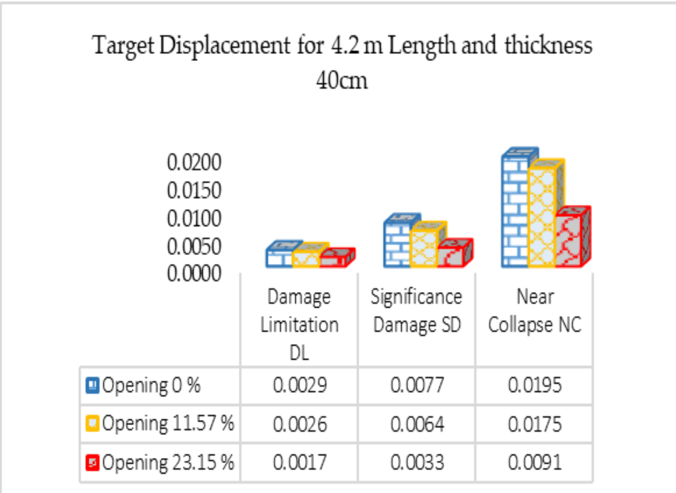



*Figure 5 (a) Pushover Curve for 5m length 40 cm Thickness and Variation of Opening, (b) Pushover Curve for 7.2 m length 40 cm Thickness and Variation of Opening.*

From the above graph ,(figure 5a) Displacement and Base Shear is to be found .It is seen that maximum displacement (0.01m) is occurred in Base shear (311.57KN) when the Opening of Building is to be zero and minimum displacement (0.0079 m) is to be noted in Base shear (261.17KN) when the opening Size is 23.15%.

From the above graph , (figure 5b) Displacement and Base Shear is to be found .It is seen that maximum displacement (0.0037) is occurred in Base shear (325.34 KN) when the Opening of Building is to be zero and minimum displacement (0.0032 m) is to be noted in Base shear (274.66) when the opening Size is 23.15%.

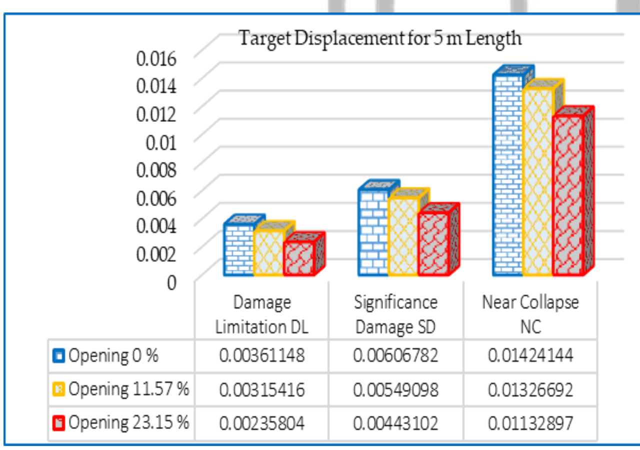
### B. Target Displacement Varying the opening size



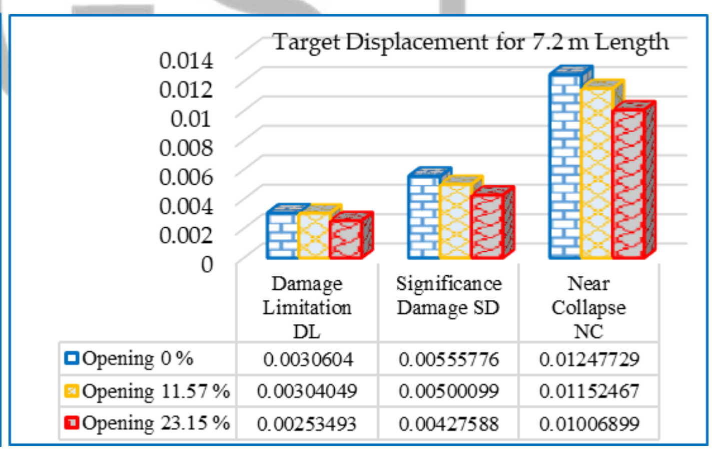

| | Damage Limitation DL | Significance Damage SD | Near Collapse NC |
|---|---|---|---|
| Opening 0 % | 0.0029 | 0.0077 | 0.0195 |
| Opening 11.57 % | 0.0026 | 0.0064 | 0.0175 |
| Opening 23.15 % | 0.0017 | 0.0033 | 0.0091 |


| | Damage Limitation DL | Significance Damage SD | Near Collapse NC |
|---|---|---|---|
| Opening 0 % | 0.0065 | 0.0095 | 0.0194 |
| Opening 11.57 % | 0.0060 | 0.0089 | 0.0185 |
| Opening 23.15 % | 0.0058 | 0.0087 | 0.0183 |

*Figure Figure 6(a) Target Displacement for 4.2m length 40 cm Thickness and Variation of Opening, (b) Target Displacement for 4.2 m length 20 cm Thickness and Variation of Opening.*




| | Damage Limitation DL | Significance Damage SD | Near Collapse NC |
|---|---|---|---|
| Opening 0 % | 0.00361148 | 0.00606782 | 0.01424144 |
| Opening 11.57 % | 0.00315416 | 0.00549098 | 0.01326692 |
| Opening 23.15 % | 0.00235804 | 0.00443102 | 0.01132897 |




| | Damage Limitation DL | Significance Damage SD | Near Collapse NC |
|---|---|---|---|
| Opening 0 % | 0.0030604 | 0.00555776 | 0.01247729 |
| Opening 11.57 % | 0.00304049 | 0.00500099 | 0.01152467 |
| Opening 23.15 % | 0.00253493 | 0.00427588 | 0.01006899 |

*Figure 7 (a) Target Displacement for 5.0 m length 40 cm Thickness and Variation of Opening, (b) Target Displacement for 7. 2 m length 40 cm Thickness and Variation of Opening.*

C. Yield Base Shear and Displacement Graph varying the opening size

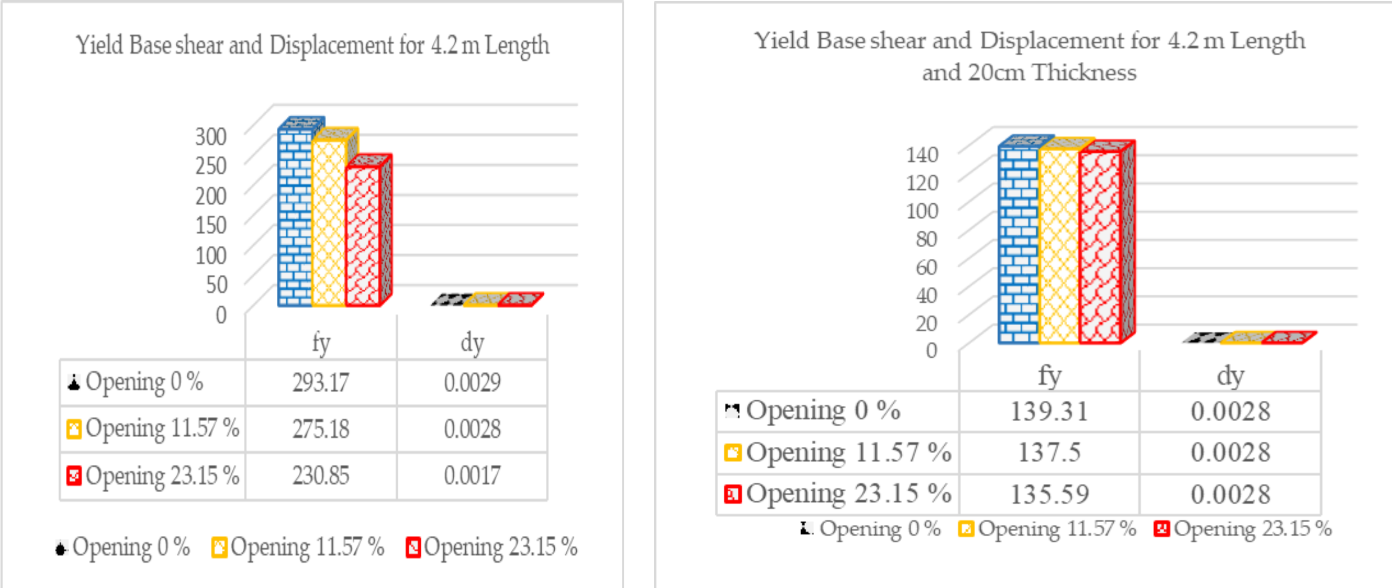



*Figure 8 (a) Yield Base Shear and Displacement for 4.2m length 40 cm Thickness and Variation of Opening, (b) Yield Base Shear and Displacement for 4.2 m length 20 cm Thickness and Variation of Opening.*

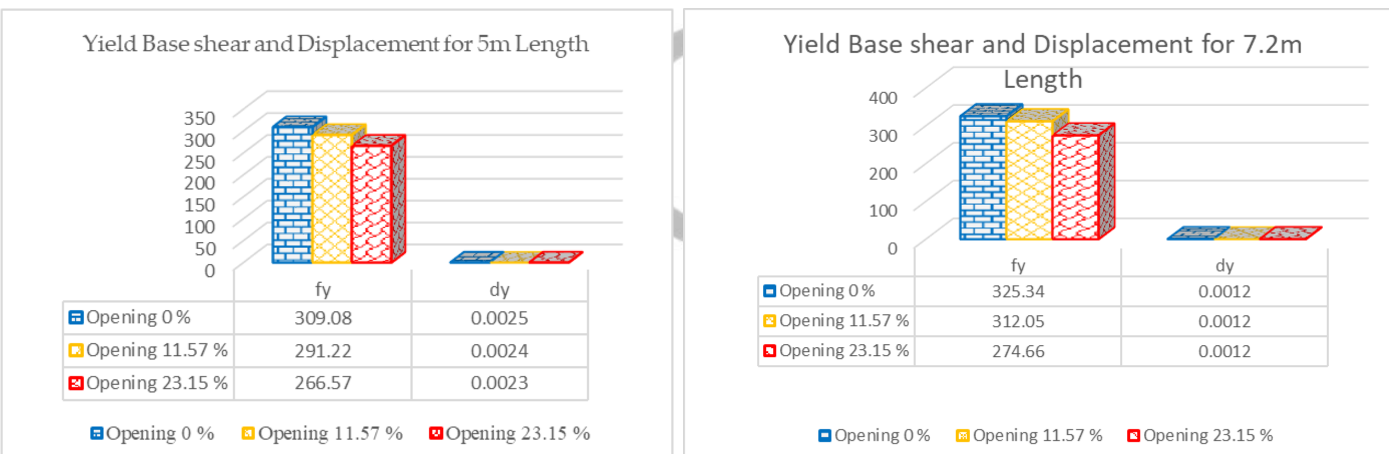



*Figure 9 (a) Yield Base Shear and Displacement for 5.0 m length 40 cm Thickness and Variation of Opening, (b) Yield Base Shear and Displacement for 7.2 m length 40 cm Thickness and Variation of Opening*

From pushover curve it is seen that Walls with a higher percentage of openings are generally less stiff compared to solid walls. This reduced stiffness can lead to larger deformations and displacements when the wall is subjected to less lateral loads. The presence of openings in a masonry wall can have a significant impact on both the base shear and displacement. More openings can reduce the wall's resistance to lateral loads, leading to a decrease in base shear and potentially undergoes collapse in lesser deformation. Conversely, fewer openings result in greater resistance, leading to a higher base shear and smaller displacements.From target displacement graph presented above, damage limit state, Significance Damage and near Collapse graph, it is observed that at with increase in damage state from damage limitation to near collapse difference of deformation between 0%, 11.57%, 23.15% opening increases that means 0% opening undergoes near collapse under large deformation than 11.57% opening and 11.57% undergoes near collapse under large deformation than 23.15% because The openings can also lead to concentration of stress around the edges of the openings, potentially contributing to cracking and deformation and undergoes collapse in lesser deformation.

## 8.2. Performance Comparison Variation on Wall Length

A. Pushover Analysis

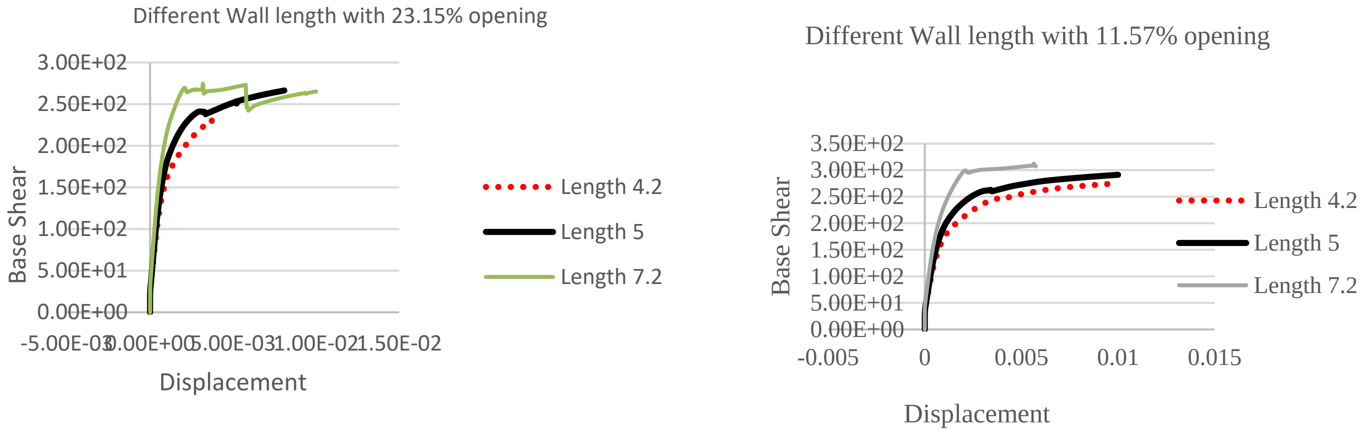



*Figure 10 (a) Pushover Curve for 23.15% Opening , 40 cm Thickness and Variation of Wall Length , (b) Pushover Curve for 11.57% Opening , 40 cm Thickness and Variation of Wall Length*

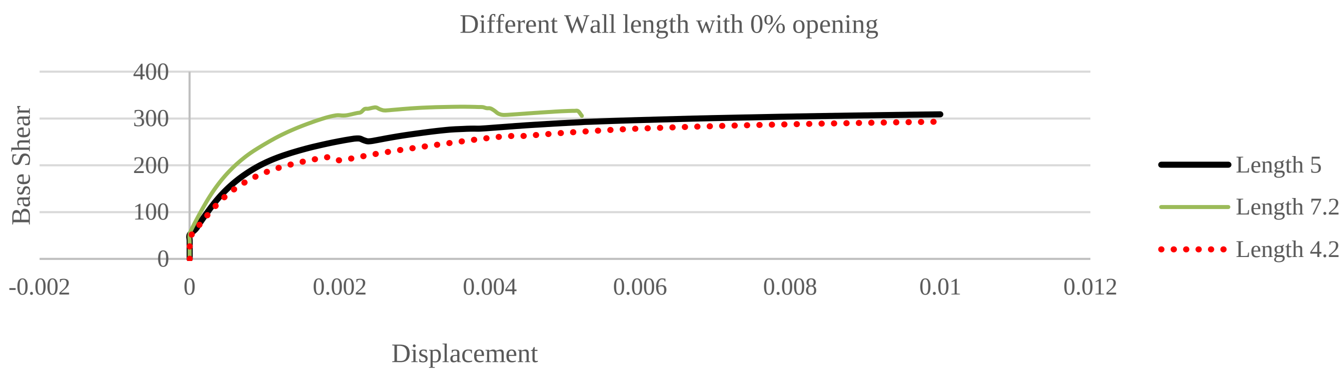
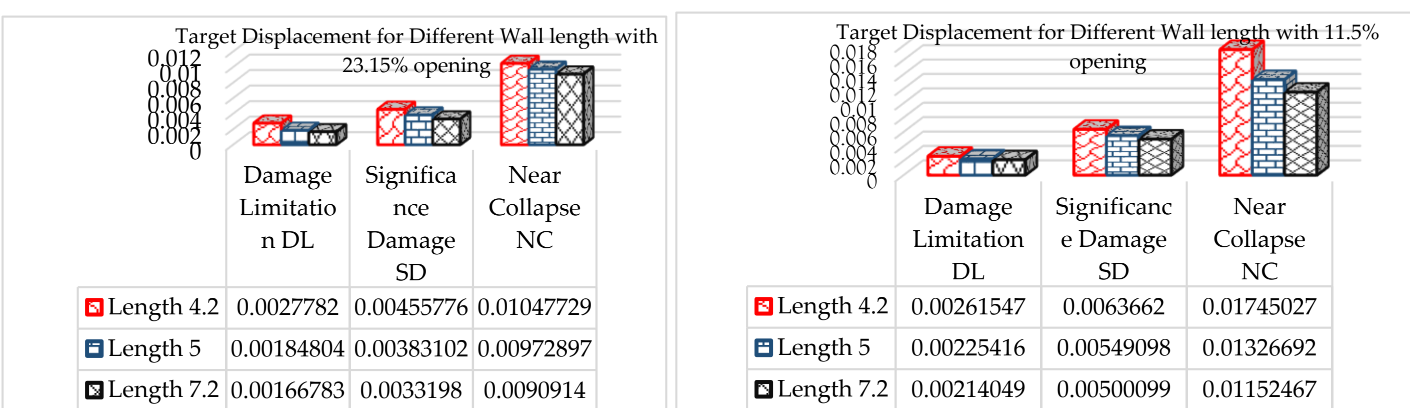



*Figure 11 Pushover Curve for 0 % Opening , 40 cm Thickness and Variation of Wall Length ,*

B. Target Displacement




| | Damage Limitation DL | Significance Damage SD | Near Collapse NC |
|---|---|---|---|
| Length 4.2 | 0.0027782 | 0.00455776 | 0.01047729 |
| Length 5 | 0.00184804 | 0.00383102 | 0.00972897 |
| Length 7.2 | 0.00166783 | 0.0033198 | 0.0090914 |

| | Damage Limitation DL | Significance Damage SD | Near Collapse NC |
|---|---|---|---|
| Length 4.2 | 0.00261547 | 0.0063662 | 0.01745027 |
| Length 5 | 0.00225416 | 0.00549098 | 0.01326692 |
| Length 7.2 | 0.00214049 | 0.00500099 | 0.01152467 |

*Figure 12 (a) Target Displacement for 23.15% Opening , 40 cm Thickness and Variation of Wall Length , (b) Target Displacement for 11.57% Opening , 40 cm Thickness and Variation of Wall Length*

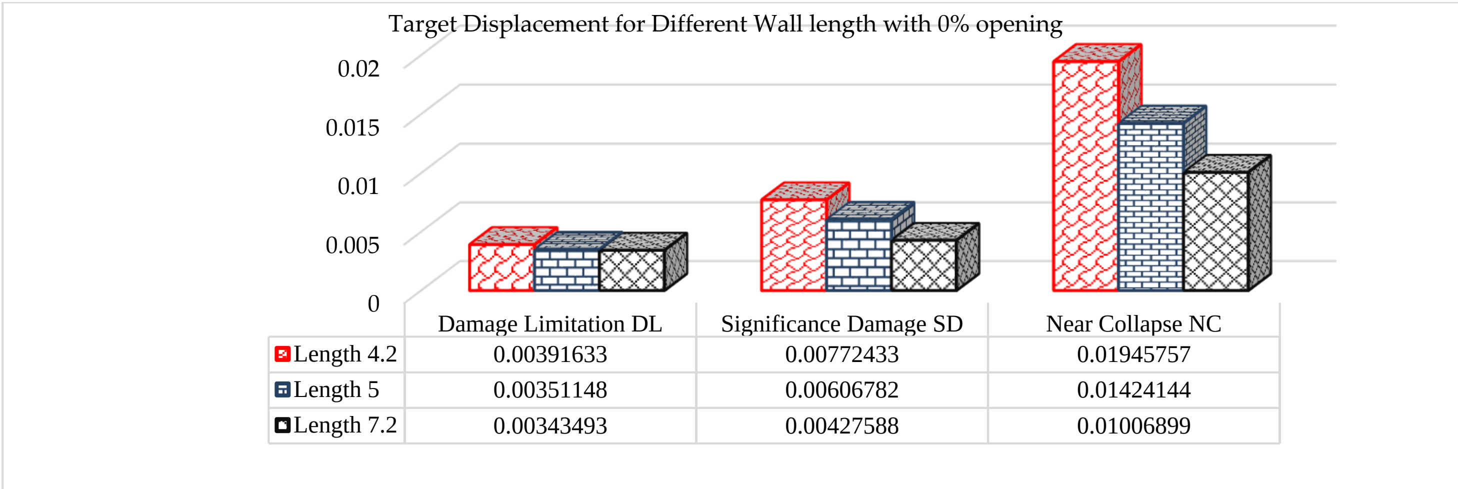



*Figure 13 Target Displacement for 0% Opening , 40 cm Thickness and Variation of Wall Length*

C . Yield Base shear and Displacement

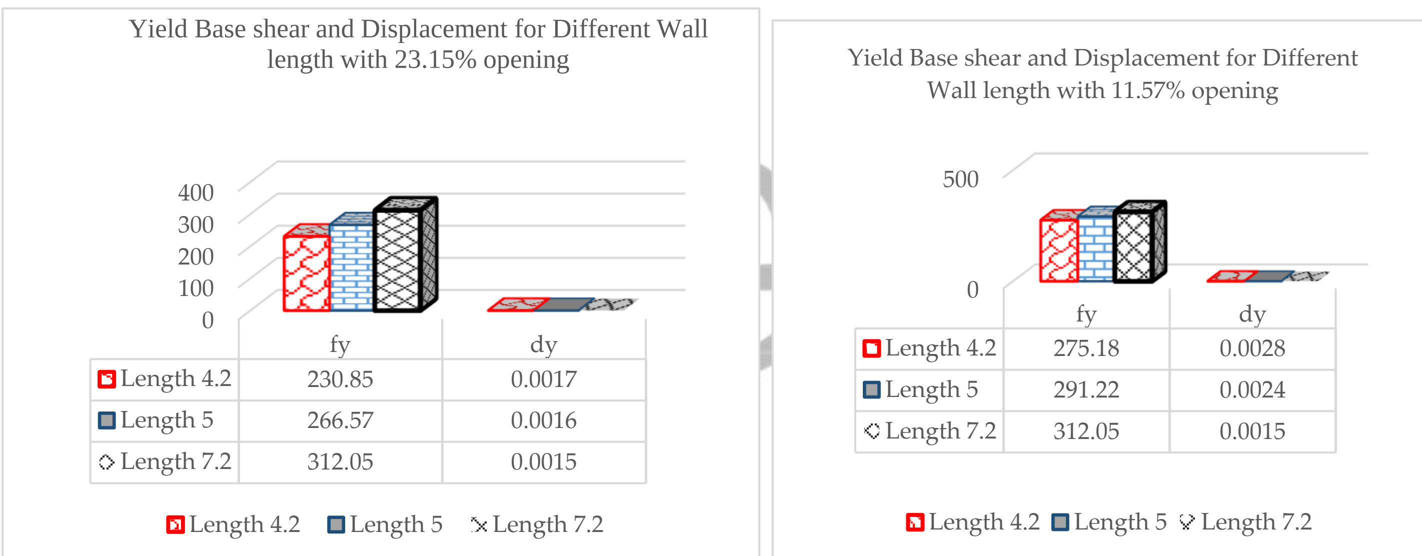



*Figure 14 (a) Yield Base Shear and Displacement for 23.15% Opening , 40 cm Thickness and Variation of Wall Length , (b) Yield Base Shear and Displacement for 11.57% Opening , 40 cm Thickness and Variation of Wall Length*

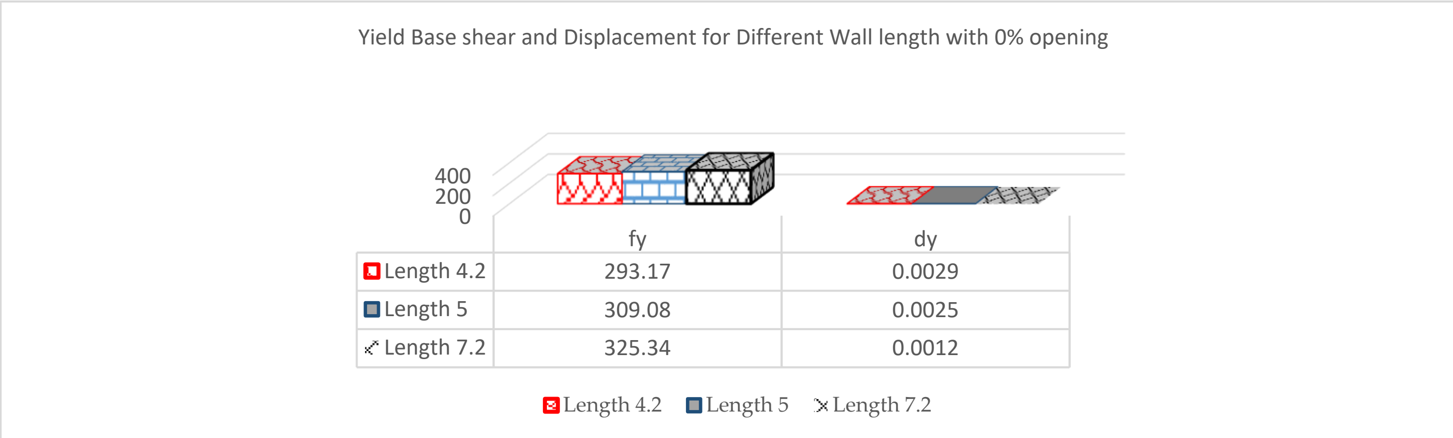



*Figure 15 Yield Base Shear and Displacement for 0 % Opening , 40 cm Thickness and Variation of Wall Length*

In the above graph , for instance, for 23.15 % opening there is significant increase in Yield base shear and de-creases in displacement for all damage stages. The observation is same for 11.57% and 0% Opening too. Thus , when the opening size is kept Constant and wall length is increases, the Yield base shear increases and displacement for different damage state decreases..

## 9. CONCLUSION

From above Result and discussion following conclusion are drawn,

1. Building with no opening/small opening shows the bet-ter performance, with increase in opening percentage in masonry wall can have a significant impact on both the base shear and displacement. Less or no opening build-ing wall higher value of base shear vs deformation. With Increase in damage state from damage limitation to near collapse buildings with less percentage of open-ing undergoes near Collapse under large deformation comparison to buildings with more percentage of open-ing. And The buildings with less opening reach to the yield point at higher yield base shear than building with more opening. The more the percentage of openings lesser will be the yield base shear.

2. Smaller length of wall undergoes collapse with large base shear but wall with long length also show better performance in base vs displacement up to yield point. And up to damage limitation it undergoes large defor-mation due to flexibility of wall with increase in length. From significance damage state to point of collapse short wall shows better performance. Short wall under-goes point of collapse with higher deformation than long wall because long wall undergoes point of collapse with less deformation

## Acknowledgment

The authors wish to thank mid west university for their support in the thesis work, of which this strudy is a integral part.

## References

[1] Depart of Population (2078), National Population and Housing Kathmandu.
[2] Fulvio parisi & Augenti Nicola (2012),Seismic Capacity of irregular unreinforced masonry wall with opening,Earthquake Engineering and structural dyanamic ,Italy
[3] Halak Sucuoglu & Erberik Altug (1997),Performance evaluation of three story unreinforced masonry building during the 1992 Erzincan Eartquake.,Earthquake engineering and structuraldynamics volume 26,Turkey.
[4] G.Prasanna Lakshmi & Dr.Helen santhi (2006),Seismic evaluation of residential building with masonry wall using ETabs,International Journal of Engineering sciences and research technology,india
[5] Rita Bento,Lopes Mario & Cardoso Rafaela (2005),Seismic evaluation of old masonry building part –I and part-II,Engineering structure,volume-27,Portugal.
[6] V. Alecci,A.G.Ayala,M.Destafeno,A.m.Marra,R.Nudo & G.Stipo (2021),Influence of the masonry wall thickness of the outcomes of double flat-jack test,Construction and Building material,Italy
[7] Bothara Jitendra & Brzev Svertlana (2011),A Tutorial on Improving the seismic performance of stone masonry buildings,Earthquake Engineering research institute,U.S.A.
[8] S.W.Chuang & Zhuge (2004),Seismic retrofitting of unreinforced masonry buildings, Australian journal of structural Engineering
[9] Zhen Liu & Crewe Adam (2020), *Effect of size and Position of opening on in-plane capacity of unreinforced masonry wall,published on bulletin of earthquake engineering.*