International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Pushover Analysis of RCC Buildings with Different Types of Shear Walls and Different Number of Spans by Frame Elements Based Model Method

Md. Mohiuddin Ahmed[1], Aysha Akter[2], Subrata Roy[3]

[1]Lecturer, Department of Civil Engineering, University of Information Technology & Sciences, Dhaka-1212, Bangladesh

[2]Assistant Professor, Department of Civil Engineering, University of Information Technology & Sciences, Dhaka-1212, Bangladesh

[3]Lecturer, Department of Civil Engineering, University of Information Technology & Sciences, Dhaka-1212, Bangladesh

Abstract: ***There are several types and shapes of shear walls depending mainly on geometry and height of the building. Both type and shape of the shear wall affect the efficiency of resisting lateral loadings. Shear walls are effective structural elements used mainly in multi-story buildings to provide resistance against lateral loadings such as earthquake and wind loadings. In this study, analytical investigation of regular shape building situated in seismic zone II of Bangladesh have been done by pushover analysis to identify the seismic demand and also pushover analysis is performed to determine the performance levels of the building with different shear walls. All Shear walls are modeled by single column model method. The performance levels and drift ratios are compared for 16 building models in both X and Y directions by using ETABS 2016 version. In this study pushover analysis based on FEMA-356 capacity spectrum method employed to analyze the building models. Pushover analysis result shows that double middle core and middle core buildings are more suitable than side shear wall and edge core buildings. All the plastic hinges developed in the buildings are in life safety performance levels. Also the building showed a weak beam and strong column behavior.***

Keywords: Pushover analysis, performance levels, shears walls, Frame Elements Based Model

1. Introduction

The pushover analysis is a static non-linear analysis under permanent gravity loads and gradually increasing lateral loads. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity.

1.1 Types of Pushover analysis

Capacity Spectrum Method: Capacity Spectrum Method is a non-linear static analysis procedure which provides a graphical representation of the expected seismic performance of the structure by intersecting the structure's capacity spectrum with the response spectrum (demand spectrum) of the earthquake. The intersection point is called performance point and the displacement coordinates (dp) of the performance point is the displacement demand on the structure for the specified level of seismic hazard.

Displacement Coefficient Method: Displacement Coefficient Method is a non-linear static analysis procedure which provides a numerical process for estimating the displacement demand on the structure, by using a bilinear representation of the capacity curve and a series of modification factors or coefficients to calculate a target displacement. The point on the capacity curve at the target displacement is the equivalent of the performance point in the capacity spectrum method.

1.2 Modeling of shear wall

- Frame Elements Based Model/Single Column Model
- Shell Elements Based Model

Frame Elements Based Model/Single Column Model: The shear walls are modeled using a set of frame elements. The most common modeling technique is to use a composition of mid-pier frame to represent the shear wall stiffness. Frame elements model also known as Single Column Model. It is the simplest model. An Equivalent column at the center line of wall section is provided. Rigid links are required to make deformation compatibility. Non-linear axial-flexural hinges are given at the top and bottom. Requires predefined hinge length. It is suitable for walls of small proportions but difficult to handle cellular core walls or walls with openings.
Shell Elements Based Model: Non-linear axial-flexural hinges are given at the top and bottom. Requires predefined hinge length. It is suitable for walls of small proportions but difficult to handle cellular core walls or walls with openings.

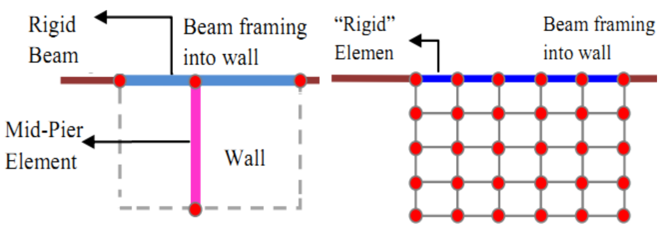

Figure 1: Mid Pier and shell elements models for shear wall

2. Methodology

- Total four types of shear walls have been considered for pushover analysis such as side shear wall (SW), edge double core (EC), double middle core (DC) and singe middle core (SC) shear wall.
- Each and every shear wall has been analyzed for three spans, four spans, five spans and six spans respectively.
- Shear walls have been modeled according to Frame Elements Based Model/Single Column Model.
- Entire analysis work has done by using Etabs 2016 version.
- At the end of the work all the data's have been accumulated and compared for better understanding of mentioned shear walls behavior under seismic loading by nonlinear analysis.

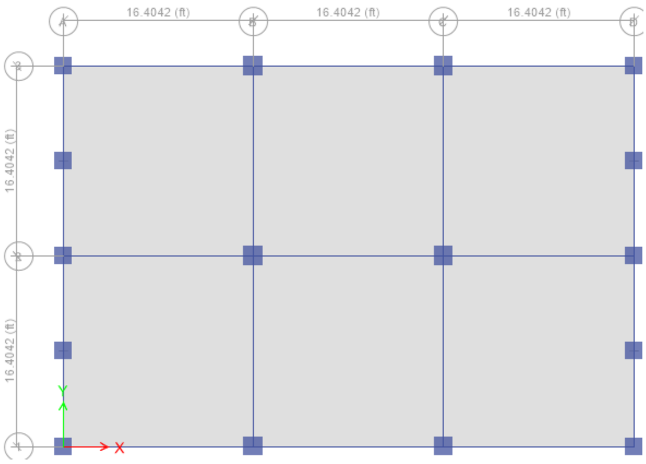

Figure 2: Plan of side shear wall building with 3spans

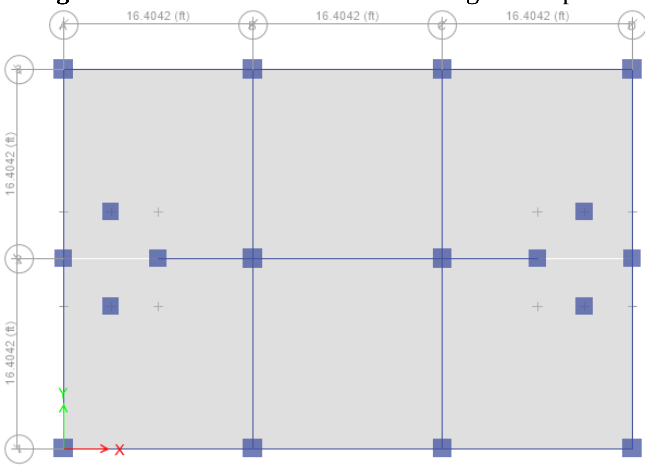

Figure 3: Plan of edge double core shear wall building with 3spans

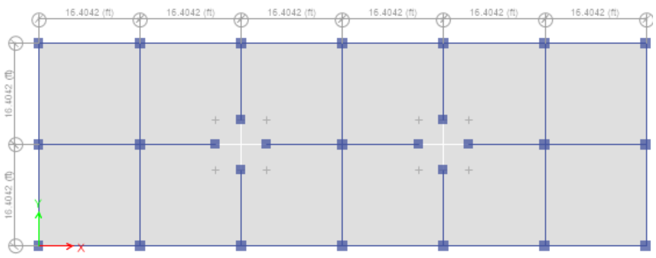

Figure 4: Plan of double middle core shear wall building with 6 spans.

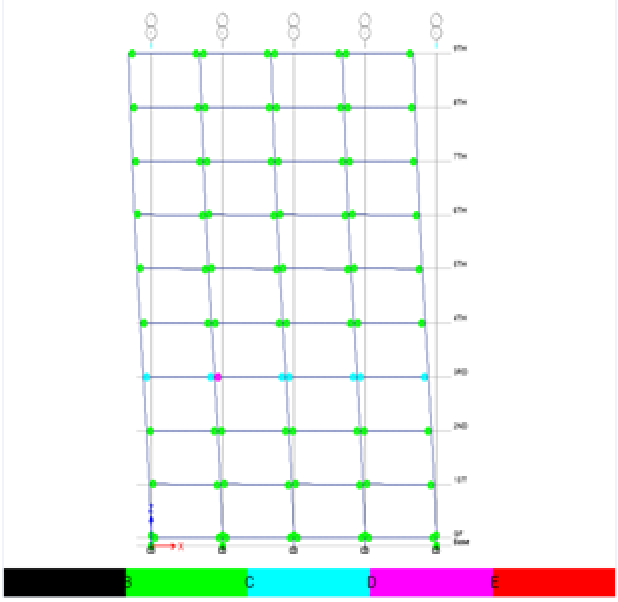

Figure 5: Step 13 for 4 spans side shear wall building

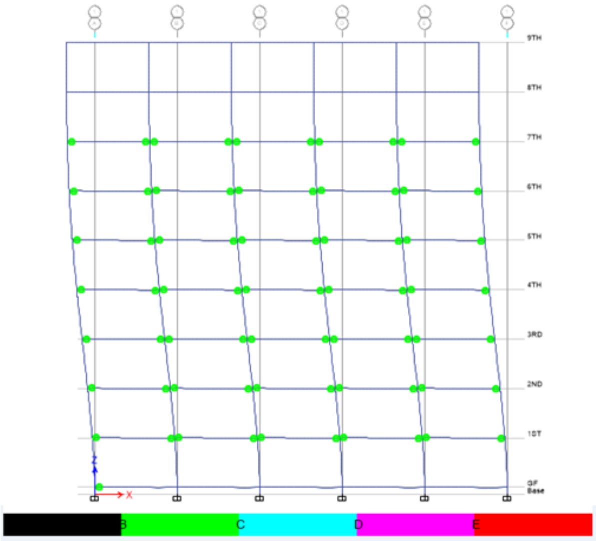

Figure 6: Performance point at step 4 for 5 spans double core building

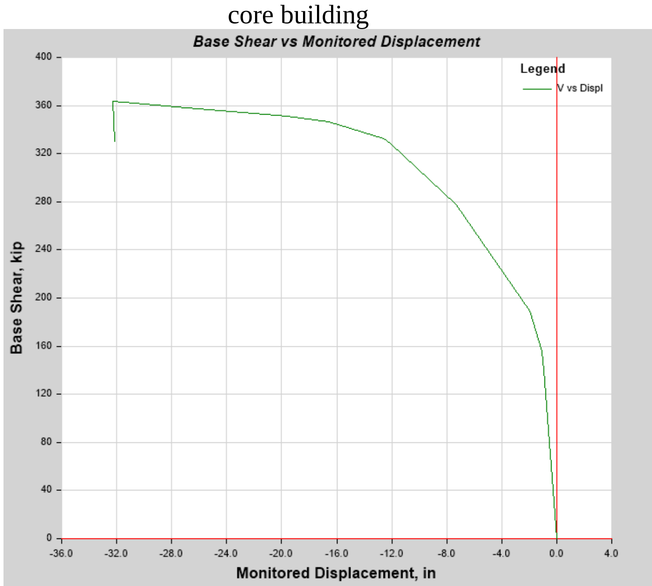

Figure 7: Push over curve for side shear wall due to Push X (3spans)

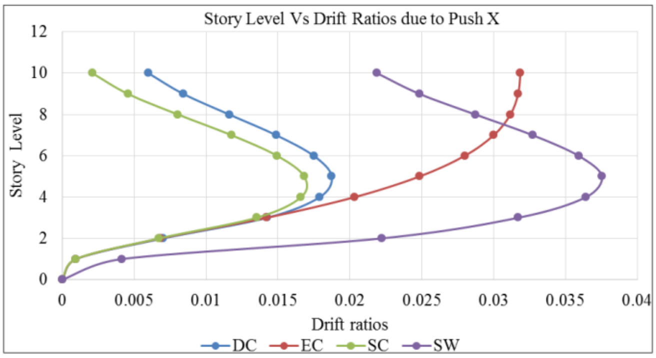

Figure 8: Comparison of drift ratios for different types of shear wall along X direction for 3 spans buildings.

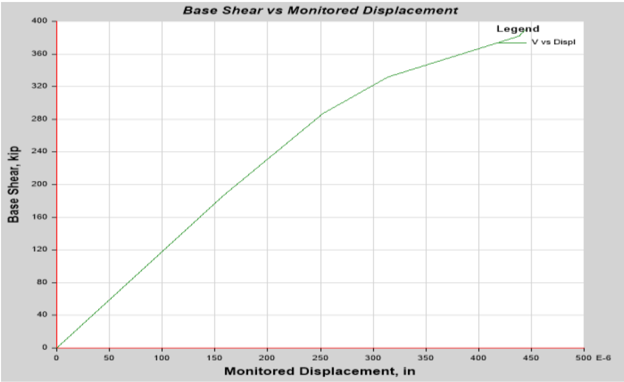

Figure 9: Push over curve for side shear wall due to Push X (3spans).

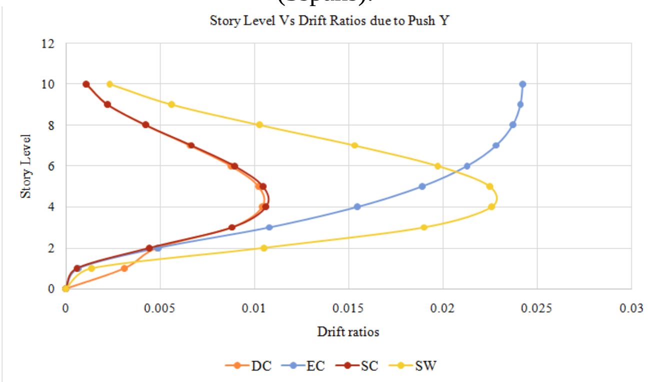

Figure 10: Comparison of drift ratios for different types of shear wall along Y direction for 4 spans buildings

3. Results and Discussions

Table 1: Performance points and number of plastic hinges in different performance levels for 3 spans building

Shear wall type	Direction	Base shear (kip)	Displacement at performance point in (cm)	Number of plastic hinges in			Total number of plastic hinges
				B-IO	IO-LS	LS-CP	
Side shear wall	X	250.282	14.32	195	63	0	258
	Y	309.710	0.00169	318	32	0	350
Middle core	X	248.851	14.07	256	0	0	256
	Y	231.609	0.00036	228	0	0	228
Edge core	X	202.339	4.72	172	0	0	172
	Y	194.53	0.000170	196	0	0	196
Double middle core	X	265.129	13.81	232	36	0	268
	Y	257.728	0.00076	240	0	0	240

Table 2: Allowable inter storey drift ratios according to FEMA-273 & 356

Structural Systems	IO	LS	CP
Masonry shear wall system	0.007	0.007	0.009
Others	0.010	0.020	0.025

Table 3: Inter storey drift ratios from software for 3 spans building

Sheer wall type	Direction	IO	LS	CP
Side sheer wall	X		0.037535 (Not Ok)	
	Y		0.020932 (Ok)	
Middle Core	X	0.01682 (Not Ok)		
	Y			
Edge Core	X	0.011688 (Not Ok)		
	Y	0.030066(Not Ok)		
Double Middle Core	X		0.01874 (Ok)	
	Y	0.00983(Ok)		

3.1 Discussion on three span buildings

- Results clearly show that all the buildings perform well during the design earthquake.
- All the plastic hinges are in performance level below the immediate occupancy (IO) and life safety (LS) level.
- Considering the performance point side shear wall performs well in Y direction and double middle core performs well in X direction than all the shear wall types buildings.
- Considering both the performance point and allowable drift ratios, it can be said double middle core building is more suitable than other types.
- Middle core building shows less displacement in both X and Y direction than the other buildings.

Table 4: Performance points and number of plastic hinges in different performance levels for 4 spans building

Shear wall type	Direction	Base shear (kip)	Displacement at performance point in (cm)	Number of plastic hinges in			Total number of plastic hinges
				B-IO	IO-LS	LS-CP	
Side shear wall	X	327.101	13.86	234	144	0	378
	Y	376.499	0.0020	332	64	0	396
Middle core	X	335.006	13.43	206	144	0	350
	Y	298.835	0.0013	242	50	0	292
Edge core	X	279.078	6.37	288	0	0	288
	Y	247.407	0.00027	246	0	0	246
Double middle core	X	333.683	13.38	374	6	0	380
	Y	322.202	0.00135	292	40	0	332

Table 5: Inter storey drift ratios from software for 4 spans building

Sheer wall type	Direction	IO	LS	CP
Side sheer wall	X		0.037248 (Not Ok)	
	Y		0.022595 (Ok)	
Middle Core	X		0.016786 (Ok)	
	Y		0.010629 (Ok)	
Edge Core	X	0.031242 (Not Ok)		
	Y	0.024243 (Not Ok)		
Double Middle Core	X		0.016874(Ok)	
	Y		0.010415 (Ok)	

3.2 Discussion on four span building

- Results clearly show that all the buildings perform well during the design earthquake.
- All the plastic hinges are in performance level below the immediate occupancy (IO) and life safety (LS) level.
- Considering the performance point side shear wall performs well in Y direction and middle core performs well in X direction for among all the shear wall types.
- Considering both the performance point and allowable drift ratios, it can be said middle core and double middle core building is more suitable than other types for 4 span buildings.
- Middle core and double middle core buildings shows less displacement in both X and Y direction than the other buildings.

Table 6: Performance points and number of plastic hinges in different performance levels for 5 spans building

Shear wall type	Direction	Base shear (kip)	Displacement at performance point in (cm)	Number of plastic hinges in			Total number of plastic hinges
				B-IO	IO-LS	LS-CP	
Side shear wall	X	403.135	13.79	300	180	0	480
	Y	435.495	0.0028	436	16	0	452
Middle core	X	381.581	13.91	286	112	0	398
	Y	357.157	0.00095	208	140	0	348
Edge core	X	350.393	6.93	360	0	0	360
	Y	314.348	0.00043	304	0	0	304
Double middle core	X	415.362	13.74	304	136	0	440
	Y	409.905	0.00096	264	144	0	408

Table 7: Inter storey drift ratios from software for 5 spans building

Sheer wall type	Direction	IO	LS	CP
Side sheer wall	X		0.037207 (Not Ok)	
	Y		0.024697 (Ok)	
Middle Core	X		0.031003 (Not Ok)	
	Y		0.011672 (Ok)	
Edge Core	X	0.031003 (Not Ok)		
	Y	0.021126 (Not Ok)		
Double Middle Core	X		0.017683(Ok)	
	Y		0.01415 (Ok)	

3.3 Discussion on five span building

- Results clearly show that all the buildings perform well during the design earthquake.
- All the plastic hinges are in performance level below the immediate occupancy (IO) and life safety (LS) level.
- Considering the performance point side shear wall and double middle core performs well in both X and Y direction among the entire shear wall types.
- Considering both the performance point and allowable drift ratios, it can be said double middle core building is more suitable than other types for 5 span buildings.
- Middle core and double middle core buildings show less displacement in X direction whereas only middle core buildings shows less displacement in Y direction than the other buildings.

Table 8: Performance points and number of plastic hinges in different performance levels for 6 spans building

Shear wall type	Direction	Base shear (kip)	Displacement at performance point in (cm)	Number of plastic hinges in			Total number of plastic hinges
				B-IO	IO-LS	LS-CP	
Side shear wall	X	478.695	13.66	360	216	0	576
	Y	455.56	0.00356	344	74	0	418
Middle core	X	484.956	13.36	360	216	0	576
	Y	423.477	0.00310	336	72	0	408
Edge core	X	496.438	13.58	332	216	0	548
	Y	420.95	0.0042	376	66	0	442
Double middle core	X	493.965	13.53	336	216	0	554
	Y	449.88	0.0026	362	56	0	418

Table 9: Inter storey drift ratios from software for 6 spans building

Sheer wall type	Direction	IO	LS	CP
Side sheer wall	X		0.037134 (Not Ok)	
	Y		0.001373(Ok)	
Middle Core	X		0.0016134(Ok)	
	Y		0.011014(Ok)	
Edge Core	X		0.016537(Ok)	
	Y		0.003455(Not Ok)	
Double Middle Core	X		0.017338 (Ok)	
	Y		0.014817(Ok)	

4. Discussion on six span building

- All the plastic hinges are in performance level below the immediate occupancy (IO) and life safety (LS) level.
- Considering the performance point edge core and double middle core performs well in both X and Y direction among the entire shear wall types.
- Considering both the performance point and allowable drift ratios, it can be said double middle core and middle core buildings are more suitable than side shear wall and edge core buildings.
- Middle core and edge core buildings show less displacement in X direction whereas only side shear wall buildings show less displacement in Y direction than the other buildings.

5. Outcomes of the study

- Pushover analysis is a relatively simple way to monitor the nonlinear behavior of the buildings.
- Position of shear wall has much significant effect on performance levels of buildings.
- All the plastic hinges developed in the buildings are within life safety performance levels.
- In three spans and five spans building the double middle core building is more suitable than other types.
- In four spans building the single core (middle core) and double middle core shear wall buildings are more effective than other types.
- In six spans building the single core (middle core) and double middle core buildings are more effective than other types.
- Also the building showed a weak beam and strong column behavior.

6. Recommendation

- In this study plastic rotation of structural elements have not been considered. So, it is being suggested to consider plastic rotation of structural elements (beam and column).
- In order to build and design a sustainable structural system, every tall building should contain adequate shear walls at suitable positions as well as the approaches of modeling the shear walls should be considered carefully during non-linear static analysis.
- In this study Frame Elements Based Model/Single Column Model has been used for shear walls modeling. Since shell element based model is more accurate than frame element model it is being recommended to follow shell element based modeling for future research works.
- A comparative study could be done between ATC and FEMA recommended codes.

References

[1] Kubin J, Fahjan M. and Tan MT (2008). Comparison Of Practical Approaches For Modelling Shearwalls In Structural Analyses Of Buildings, The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China
[2] Nicolae I and Reynouard JM (2000). Nonlinear analysis of reinforced concrete shear wall under earthquake loading, Journal Of Earthquake Engineering, 4: 2, 183-213
[3] Samir A.B. Jabbar Al-jassim, Mohanned Abdul Husssain (2018). Pushover Analysis of G+5 Reinforced Concrete Building in Basrah, International Journal of Innovations in Engineering and Technology (IJIET) 11: 1,53-59
[4] Syed Ahmed, Dr.Jagadish.G.kori (2013). Performance based seismic analysis of an unsymmetrical building using pushover analysis, International Journal of engineering research online. 1:2, 100-110.
[5] FEMA 356 (2000). Pre-standard and commentary for the seismic rehabilitation of buildings, american society of Civil Engineers, Reston, Virginia
[6] Federal Emergency Management Agency, Guidelines and Commentary for the Seismic Rehabilitation of Buildings, FEMA 273 & 274, 1998