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Seismic Performance Evaluation of Reinforced Concrete Shear Wall Building with End Return

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Abstract

The design of Reinforced concrete civil engineering structure is often based on standardized methods of building codes, so is the load and our design are based on the assumption on the result in elastic structural behavior. However, under a strong earthquake event, the structure may be exposed to the forces beyond its elastic limit, as re-occurrence of earthquake is frequent in our country earthquakes indicate the vulnerability of various inadequate structures, each time they occur. Shear walls have been the most common structural elements used for stabilizing the building structures against horizontal forces, meanwhile study on proper location and performance of shear wall showed that the shear wall with flange represents an effective solution for strengthening the structural system as it enhances the rigidity for the lateral load resistance due to interaction of web and flange [1]. The present study is carried out with Equivalent static load analysis of a buildings varying from nine storied to twenty first storied in ETABS version 18.0.2. From equivalent static analysis procedure structure response like maximum drift, displacement, time period and base shear has been calculated and comparison has been made. It is found that Shear Wall with end return enhances the property of shear wall to resist the lateral forces, torsion perpendicular to its plane by enhancing rigidity.

Keywords

Equivalent Static Procedure, shear wall, end return

1. Introduction

Nepal geography is susceptible to earthquake and frequent reoccurring earthquakes has given lessons that failure of Reinforced concrete (RCC) structure mainly attributed to lack of knowledge of good construction practices, poor building material quality, insufficient detailing of reinforcement, lack of transverse steel and confinement of concrete in structural element. However, in the recent earthquake, even buildings with RCC walls that were not specific to the seismic activity but had sufficient reinforcement were saved from the collapse[2]. Shear wall structures are common practice in many earthquake-prone countries to resist most efficiently the various combinations of gravity and horizontal loading, providing structures with sufficient stiffness while minimizing deformations and damage to non-structural elements. Shear walls are easy to build, since the emphasis on wall specifications is straight forward and therefore easily made on site. Shear walls are efficient both in relation to the performance and construction cost [3]. Shear walls are also capable of providing sufficient strength, deformation, and energy dissipation capacities when subjected to severe seismic excitations to prevent collapse and casualties. There are several types and shapes of shear walls depending mainly on geometry and height of the building [4]. Shear wall meeting each other at right angles result in flanged configuration. In this case end return is used to describe a perpendicular shear wall that is joined at the corner of the building to a shear wall that is acting parallel to the lateral force in the form of L Section.

Flanged walls are some of the most commonly used members in real structures. However, the seismic behavior and performance of the L or T-section walls possess distinct features from rectangular ones. The shear force is almost entirely sustained by the web while moment is sustained by both the web and the flanges.[5] Due to the presence of flange concrete and reinforcement, flanged walls generate much greater moment resistance than rectangular walls with the same length. Since the demand of shear is determined by the actual axial-flexure [6][7], increase in moment resistance will boost up the shear level in the web. Consequently, the resistance of shear force in the web may be more critical.[8] Ductility is significantly higher when the flange is in compression, and much lower when it is in tension.[9] Mechanical characteristics of an L-section (end return) shear wall may change significantly along different directions, which could lead to unexpected failure modes.[10] In addition, performance of two orthogonal directions are coupled and interrelated.[11] Many engineers currently develop their seismic rehabilitation designs with the assumption that only walls in the direction of the applied loads are effective in resisting lateral forces. The walls in directions orthogonal to the loading are disregarded and the effect of flanges that occur when walls intersect is not considered. This oversight may lead to extremely inaccurate representations of buildings' response to earthquakes, particularly in tall buildings when the flanges are fully effective under lateral loads. Given the considerable difference from rectangular walls, it is thus necessary to gain insight into the L-section (end return) wall seismic performance.

2. Objective

The main objective of the research is to investigate seismic Performance of RCC Shear Wall Building with End Return

3. Methodology

To get the knowledge database of the research work, detailed project related literature review is carried out. Equivalent static analysis was performed in finite element software ETABS version 18.0.2. based on IS1893:2016 [12] to address the objective. For this 24m x 24m Simple plan configuration buildings varying from nine storied to twenty first storied with shear wall of 230mm thick and 3m long will be introduced at corner along one axis and proportionately increasing end return at 0.5m till 3m along other axis to observe the performance of the building. The responses will be seen on horizontal displacements, storey drifts, fundamental periods, base shears, with addition of end return will be examined.

4. Building Description

Building used for study are nine, twelve, fifteen, eighteen and twenty-one storied RCC building in Kathmandu valley on medium soil condition with importance factor of 1. The floor height considered is 3m and typical Floor plan measures 24m x 24m with 3 x 3 bays shown in figure 1. The Building was analyzed per IS 1893(Part I):2016[12].The Sectional Properties considered are column 500mm x 500m, Main Beam 300mm x 500mm, Secondary Beam 230mm x 450mm and Slab thickness 125mm Whereas gravity loads used accounts self-weight of member as well as Floor finish 1.15KN/m^2,Partition Load 1.2 KN/m^2, live Load 5KN/m^2 and masonry Loading[13].

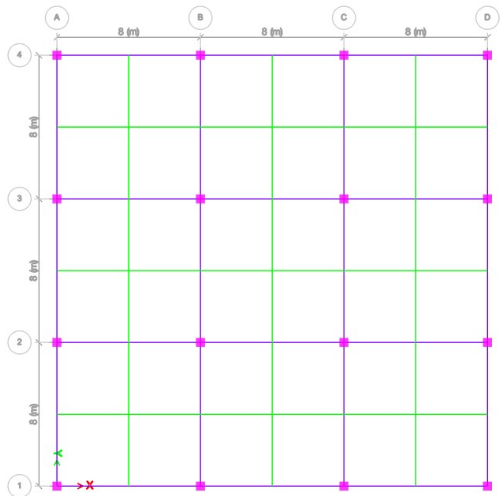

Figure 1: Typical Floor Plan

5. Anlysis and Results

The buildings have been modelled as 3D frame using "ETABSV18.0.2". The software has very good analysis and design capability which are verified in the verification problems included in the package. Almost all seismic code permits an Equivalent Static Procedure for the design of regular building where the design base shear is computed as a fraction of the seismic weight, based on factor such as seismic zone factor, importance of the building, Response Reduction Factor, fundamental time period and type of soil.

In this case the model has been designed as a dual system, i.e. moment-resisting frame must be capable of resisting at least 25 percent of the base shear, and the two systems must be designed to resist the total lateral load in proportion to their relative rigidities as both frames and shear walls contribute in resisting horizontal forces. Frame bends in accordance with shear mode, whereas the deflection of the shear walls is by a bending mode as a result of the difference in deflection properties between frames and walls, the frames will try to pull the Shear Walls in the top of the building and try to push the walls at bottom. So, the frames will resist the lateral loads in the upper part of the building, while the Shear Walls will resist most of the vertical loads in the lower part of the building.[11] Since this phenomenon is employed in analysis of building and choice of shear wall thickness and length is based upon this fact column remain safe from collapse.

After modelling and analysis, the results are organized to meet the research objectives. For different cases performances of structures were evaluated with the help of horizontal displacements, storey drifts, fundamental periods, base shears under systematic review process.

Maximum storey drift response of the buildings for different variation of end return length and height is presented in table 1 and table 2.Result shows that 1m end return shear wall is sufficient for 12 storey building,1.5m end return in 15 storey,2.5m in 18 storey and 3m in 21 storey building to limit the drift within permissible limit.. There is quite optimistic result in drift performance this may be due to fact that optimal Location of Shear wall position suggest that more number of shear wall panels are not necessarily effective in reducing the overall displacement of structure but the type of arrangement had significant effect. Shear wall located at periphery of building had better performance in controlling response like drift, displacement and smaller value of member forces.[14] So the shear wall with end return has shown quite good response in response management.

While, fundamental time period and base shear result of the different model with variation of end return length are presented in Table 3 and table 4.

Figure 2, Figure 4, Figure 6 and Figure 8 Shows the storey displacement of the different model with variation of end return length along X-direction. Meanwhile, Figure 3, Figure 5, Figure 7 and Figure 9 gives displacement performance enhancement of fixed shear wall along Y-axis due to introduction of end return.

Analysis results show that maximum drift control performance of shear wall is enhanced by 4% for 12 and 15 storey building while 10% for 18 and 21 storey in response for drift control. Also, the top floor displacement limitation has been improvised by 12% for 12 and 15 storey buildings while 22% for 18 and 21 storey buildings with addition of end return.

Table 1: Maximum Storey Drift For Different height Models

Maximum Drift Value				
Endreturn	Drift 12 Storey		Drift 15 Storey	
	EQX	EQY	EQX	EQY
No Wall	0.44%	0.44%	0.57%	0.57%
0	0.43%	0.27%	0.55%	0.29%
0.5	0.41%	0.26%	0.52%	0.28%
1	0.35%	0.25%	0.47%	0.27%
1.5	0.32%	0.24%	0.39%	0.26%
2	0.29%	0.24%	0.32%	0.26%
2.5	0.26%	0.24%	0.28%	0.25%
3	0.23%	0.23%	0.25%	0.25%

Table 2: Maximum Storey Drift For Different height Models

Maximum Drift Value				
Endreturn	Drift 18 Storey		Drift 21 Storey	
	EQX	EQY	EQX	EQY
No Wall	0.69%	0.69%	0.81%	0.81%
0	0.67%	0.38%	0.79%	0.48%
0.5	0.63%	0.34%	0.75%	0.44%
1	0.58%	0.32%	0.69%	0.41%
1.5	0.50%	0.31%	0.61%	0.39%
2	0.42%	0.30%	0.52%	0.38%
2.5	0.34%	0.29%	0.44%	0.37%
3	0.29%	0.29%	0.37%	0.37%

Table 3: Time period for different height model

Time Period in Sec					
End Return	Load Pattern	12 Storey	15 Storey	18 Storey	21 Storey
No End Return	EQx	4.59	5.78	6.97	8.17
	EQy	2.99	3.97	4.99	6.04
0.5m	EQx	4.42	5.58	6.75	7.92
	EQy	2.8	3.74	4.73	5.75
1m	EQx	4.04	5.17	6.32	7.47
	EQy	2.68	3.6	4.57	5.56
1.5m	EQx	3.59	4.68	5.78	6.9
	EQy	2.61	3.51	4.46	5.44
2m	EQx	3.17	4.19	5.23	6.3
	EQy	2.55	3.44	4.38	5.35
2.5m	EQx	2.8	3.75	4.73	5.74
	EQy	2.51	3.39	4.32	5.28
3m	EQx	2.48	3.36	4.27	5.23
	EQy	2.48	3.36	4.27	5.23

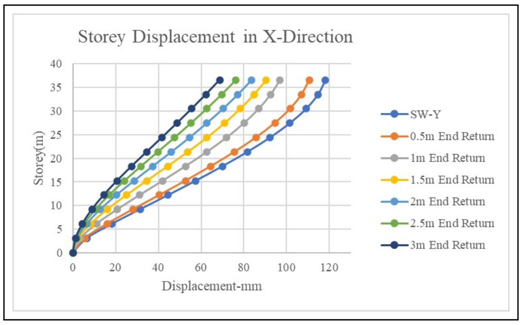

Figure 2: 12 Storey Building Storey Displacement in X-Direction

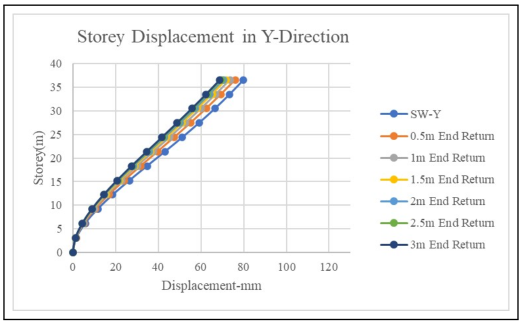

Figure 3: 12 Storey Building Storey Displacement in Y- Direction

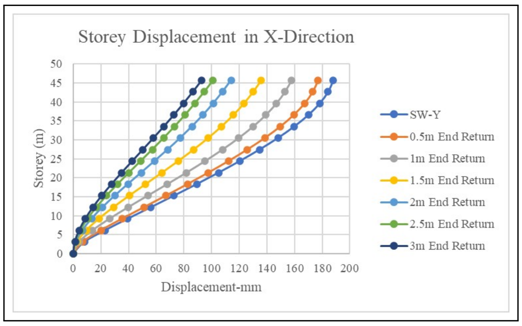

Figure 4: 15 Storey Building Storey Displacement in X- Direction

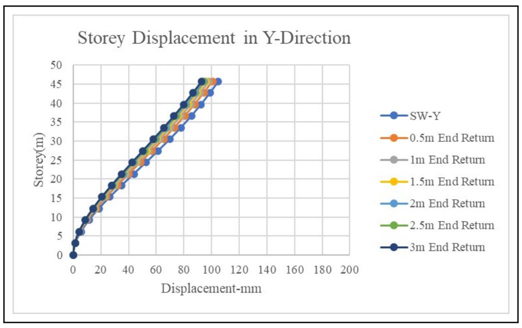

Figure 5: 15 Storey Building Storey Displacement in Y- Direction

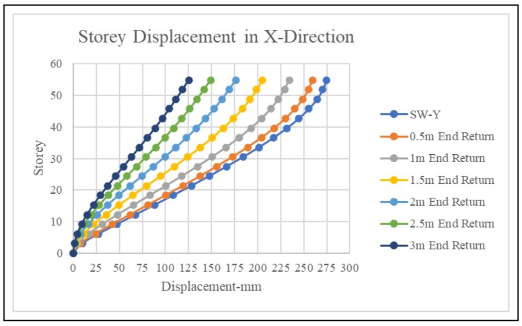

Figure 6: 18 Storey Building Storey Displacement in X- Direction

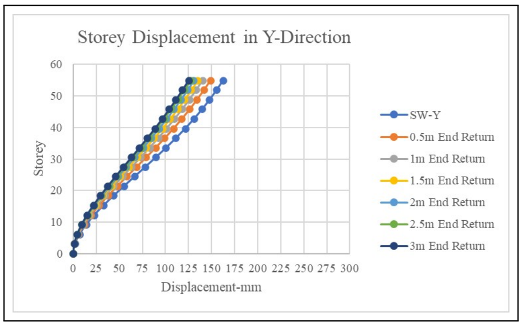

Figure 7: 18 Storey Building Storey Displacement in Y- Direction

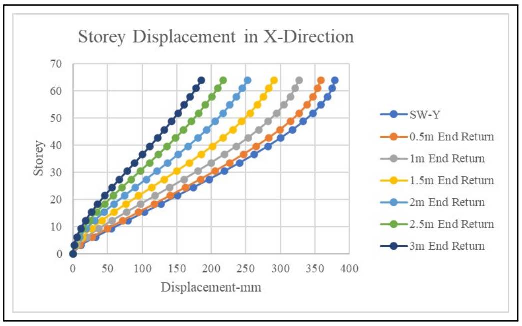

Figure 8: 21 Storey Building Storey Displacement in X-Direction

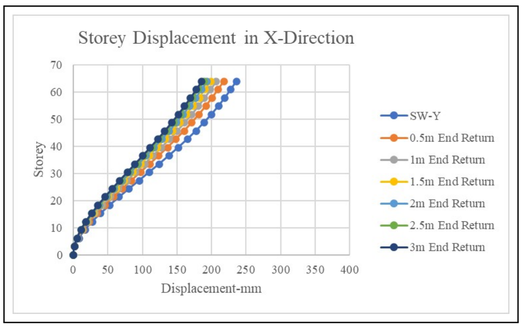

Figure 9: 21 Storey Building Storey Displacement in Y-Direction

Table 4: Base shear for different height model

Base Shear in KN					
End Return	Load Pattern	12 Storey	15 Storey	18 Storey	21 Storey
No End Return	EQx	1219	1525	1830	2136
	EQy	1631	1536	1830	2136
0.5m	EQx	1224	1531	1838	2145
	EQy	1751	1637	1838	2145
1m	EQx	1229	1537	1845	2153
	EQy	1834	1707	1845	2153
1.5m	EQx	1374	1543	1853	2162
	EQy	1895	1759	1853	2162
2m	EQx	1563	1550	1860	2171
	EQy	1943	1800	1860	2171
2.5m	EQx	1776	1661	1868	2180
	EQy	1982	1834	1868	2180
3m	EQx	2015	1862	1875	2189
	EQy	2015	1862	1875	2189

6. Conclusion

Based on the analysis the following conclusions are drawn:

- Response of analysed building shows that drift and displacement results have been highly influenced by end return. Thus, this result can be conveniently used to design high rise building with end return to assure the better performance of structure.
- In comparison to bare frame time period has decreased as the structure tends to behave like RC Structural Wall Building.
- The base Shear has constantly increased with addition of end return due to addition of mass in building.
- Shear Wall with end return enhances the property of shear wall to resist the lateral forces, torsion perpendicular to its plane by placement of end return.

The research can be further extended to evaluate the performance of the building by analysing with dynamic analysis. Further, different plan configuration and irregular building can be evaluated.

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