The Ninth International Conference on Construction in the 21st Century (CITC-9)
"Revolutionizing the Architecture, Engineering and Construction Industry through Leadership, Collaboration and Technology" March 5th-7th, 2017, Dubai, United Arab Emirates

Study the Effective Location of Shear Wall and Its Cost of Multi-Story Building Under Seismic Loading in Iraq

Mohammed Alrubaye
Technical University of Civil Engineering of Bucharest, Romania
eng.mohammed.adhari@gmail.com

Nicolae Postavaru
Technical University of Civil Engineering of Bucharest, Romania
nicolae.postavaru@gmail.com

Abstract
The present research aims to study the response of multi-story framed building subjected to seismic loading. The finite element dynamic analysis is applied through using **SAP2000** software and using nonlinear static analysis in the study. The study includes calculating the free vibration analysis and the forced vibration due to earthquakes loading. The main factors considered in this study are the location of the shear wall and the type and economy cost of these types. The record of earthquake in Iraq is applied on a three dimensions multistory building with practical size and the response is determined and discussed. In our study will search the effective of the location and type of shear wall in the response of the building under earthquake loading and also we discuss the economy state for each case and compare between it to find the perfect case have good results under seismic loading and also have good economy cost. In our study, search the free vibration analysis and also can make forced vibration analysis under seismic loading. The study also uses multistory building above 15 story and the shear wall install along the building length and different location in center of the building, external corner, internal corner, and each parallel side in external and internal the building and also using different shape of share wall like angle and rectangular.

Keywords
Seismic Load, Shear Wall, Cost Management, Nonlinear Static Analysis, SAP2000

1. Introduction

Shear wall can be defined as any structural element that gives stiffness, strength and stability and is designed as a framed structure. Concrete walls such as shear walls and lift wells are normally used in multi-story buildings. Most people prefer it because of its ability to withstand strong winds and earthquakes. The structure is ideal by using mass center and coinciding centroid. A shear wall is normally required to stiffen the building. Thus, the function of shear wall is to increase the rigidity of structural system. Shear walls are normally used to construct modern building and make them appear vertical in nature. Lateral forces caused by blowing wind can make a building snap and bend over time. Therefore, there is need to use a shear wall to prevent such damages from taking place. Shear wall is used to provide earthquake resistance to concrete buildings. Building built using shear wall do not collapse easily even if there is an earthquake. In addition, the walls are used to separate enclosed close spaces. The shear wall can be 150 mm thick or 400mm high. The way the structure behaves depends on stiffness, weight distribution; and strength of both the vertical and horizontal plane in a building. The shear walls are used in reducing earthquake effects. Furthermore, shear walls can also be used to improve a building's seismic response.

The seismic response is used to minimize the extent of earthquake on tall buildings. Shea walls are normally used in tall buildings to prevent them from collapsing. If done properly, shear walls can be useful in lateral force resisting. It is important to carry out an investigation on the appropriate location for placing the shear wall. Shear walls has gained a lot of popularity in construction of high buildings such as commercial towers. Therefore, shear walls has been found to be economical and effective for multi-story building. It is suitable for multi-story buildings of about 30 to 35 stories. Evidence shows that for the last 30 years no building constructed using shears walls has ever collapsed even when there are earthquakes and strong winds (fintel, 1995). Thus, shear walls are preferred by many for constructing of buildings. For this study, different types of structures were used. There are structures without a shear wall and those that had a shear wall. The criteria that is used in RCC designing is in seismic zones is lateral displacement from lateral forces. Investigations have been carried out to determine the most convenient location that can be used for lateral displacement of shear wall and also the base shear RCC frames. The location is an important consideration when it comes to constructing shear walls. The location will determine how long the building will remain standing without being damaged. Nonlinear statistical analysis also known as the pushover analysis was use to carry out the analysis on different kinds of models. Base shear and displacement are calculated from curves and then the two are compared against each other. Nonlinear analysis is an important tool in studying concrete behavior. The analysis helps in identifying the different characteristics of the concrete. Therefore, nonlinear analysis is a suitable method for giving an analysis on concrete behavior. Furthermore, it gives results that are easy to interpret.

2. Objective of the study

The main objective of the study is to out how effective shear wall will be if it is placed at the right location.

3. Reinforced concrete shear walls

The reinforced concrete are normally vertical plate like walls. The reinforced concrete structure should be designed in such a way that they are able to carry combined loads like seismic loads, live and dead loads at a given level of safety. It should not be difficult to use reinforced concrete in such any kind of load. Therefore, it is vital to have an account of material properties, loads, method of analysis and structural system. Such information helps in identifying the amount of concrete that will be used for the construction. Additionally, having an account of material s convenient becomes it makes it a lot easier to determine how much material will be required. The walls are continuous for the entire part of the building. Breaking the walls will make it easy for the walls to become damaged in a short time. As such, there is need to take a lot of precaution before starting the construction work. The thickness of the walls are 150mm low and 400mm high in tall buildings. Shear walls play an important role in resisting earthquakes. It is for this reason that they have become popular in construction projects. According to one of the consulting engineers in the United States, Fintel (1995), there is no way concrete walls can be built without the use of shear walls. The statement shows just how important shear walls have become in almost every construction project.

Reinforce concrete shear walls give buildings stiffness and strength depending on their orientation direction. Therefore, RC walls help in reducing lateral sway and thus reducing the damage to the building and its contents. Shear walls have a large overturning effect because they support large earthquake forces. In order to reduce the effects of twist in structures, shear walls have to be symmetrical. It is the only way to avoid having massive losses. The walls can be placed in any direction but they have to be symmetrically placed. For shear walls to be effective, they have to be located along an exterior perimeter. There is need to stress on the location f the shear wall since it determines whether the building will withstand earthquakes or not. Making use of the exterior perimeter helps reduce the chances of the building succumbing to twisting. Therefore, no construction work should lack the exterior perimeter.

4. Shear walls function

There are numerous benefits that shear walls offer to building. First of all, shear walls have to provide the strength needed to resist earthquakes. If the shear walls are stronger then it will be a lot easier for them to transfer their horizontal forces to the element that follows. The next element may be a floor, shear wall, foundation walls, footings or slabs. It does not matter the type of element. What matters is whether the shear wall is able to transfer the horizontal forces. In case the shear wall does not transfer the forces, then it increases the chances of the building being damaged. Apart from that, shear walls give lateral stiffness required to prevent floor or roof from side sway. Additionally, stiff shear walls help prevent roof and floor from shifting away from their supports. Furthermore, stiff buildings do not have nonstructural damage. The function of shear walls in any building cannot be stressed enough.

4.1 Analysis

The analysis of the building is done by using the SAP 2000 software. The software is used to run all the analysis. The software can predict the nonlinear behavior under dynamic and static loadings while taking into account the material inelasticity and geometric nonlinearity. The SAP2000 works well with both dynamic and static loads. It can also perform nonlinear dynamic analysis and nonlinear static pushover. The software I a convenient means for conducting the analysis on shear walls. The models used were designed in the SAP2000 software using different section of the reinforced shear wall, cross type, L type, box type shear wall. The sections are located in different areas like at corner, along periphery, and middle positions. They locations are separated in that manner to determine the appropriate location for placing the shear wall.

The buildings used are modeled to resist load elements. Therefore, there is no need to worry about exceeding the load elements. The loads to be applied on the structures are from Iraq standards. The standards are from Iraq since that is where the study will take place. The buildings used in the study have both brick masonry and reinforced concrete elements. This is to help determine the most convenient concrete for use with shear walls. It is assumed that the frames are fixed firmly at the bottom of the structure. Therefore, they will not interrupt in any way with the construction of the shear walls. The construction process will therefore be done without any interruption.

4.2 Nonlinear static analysis

The pushover analysis is a nonlinear procedure whereby lateral loads magnitudes is increased thus giving a predefined distribution on the height of the structure. Pushover analysis can be used to determine how a building behaves.

4.3 Purpose pushover analysis

The pushover analysis is normally used to give an evaluation of expected performance of buildings. The performance is evaluated by analyzing the deformation and strength demands. The pushover analysis is normally carried out for all models. Therefore, it is suitable for use in this study.

4.4 Problem statement

To carry out the analysis, the model of a reinforced building and the plan area that has been selected is in Iraq. The height fit eh story building is about 3.5 m while the height of floor-to-floor is three. The spacing frame to be used is 4m. The concrete used for the analysis is M20 while the structural steel is Fe415.The structural properties to be used for the reinforced concrete shear as are; shear wall thickness of 200mm, total depth of the slab will be 120mm, the external thickness of the wall is 250mm, the internal thickness of the wall is 150mm, the external column size is 300 by 530mm, the zone factor is 0.1, the importance factor is 1, and the response reduction factor is 3.

4.5 Methodology

This section looks at the methodology of the study. It gives a clear explanation of the methodology used to conduct the study. There are assumptions used in conducting the study. The building has 20 stories. The columns are assumed to be fixed. The slab is 0.15m for all the stores; the floor-to-floor height is 3.5m. The live load on roof is 4 kN/m^2, the floor finish is 1kn/m2, the live load on the roof is 1.5 kN/m^2. The wall thickness for all the beams is set at 230mm. The seismic weight is24kN/m^2. The concrete grade used is M-30 for the slab and M-40 for the beam.
The models that were used in the analysis were;
- Buildings with shear walls and uniform thickness
- Building with shear walls and varying thickness

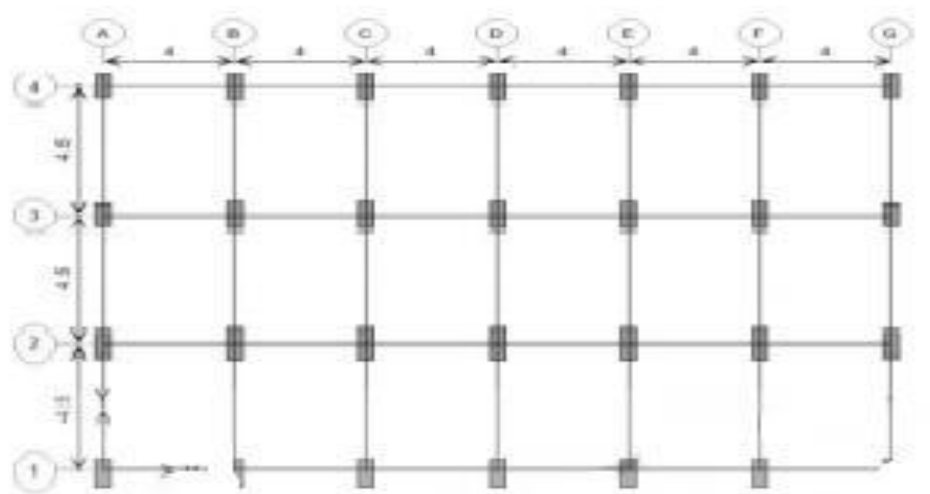

Figure 1: Plan design of 20-story building

5. Result and discussion

The analysis as carried out to determine how concrete structure perform under seismic loading. The results in form of story drift and story displacement and the result variation has been discussed. The method used to carry out the building analysis is nonlinear static method. Furthermore, the variation of the story drift and story displacement for building with shear walls with varying and uniform thickness has also been discussed. The results are as follows:

5.1 Displacement

As it is evident from the figures below, the displacement of the story, reduce when a T2-B model is developed. The maximum displacement is on the T2-A model while the minimum displacement is T2-B model. The reduction in displacement of the stories is as a result of the increase in structure stiffness and even on the velocity, the displacement is lowest on the stories at the bottom and is high on the upper stories. The displacement is with regards to the structural strength, stability and human comfort. Given that the displacement for T2B is less as compared to the other model; its means that the T2B is more stable.

Table 1: Story displacement of type 1 model

STOREY	T1AUX	T1BUX	T1CUX	T1DUX
Story 1-20	691.2504	589.1949	541.6675	663.5825
Story 1-19	649.398	553.0885	506.8151	624.6544
Story 1-18	607.0139	516.5876	471.8105	585.0707
Story 1-17	564.1682	479.7782	436.7386	544.9033
Story 1-16	520.971	442.7754	401.71	504.2648
Story 1-15	477.5823	405.7243	366.8603	463.3127
Story 1-14	434.2087	368.7959	332.3418	422.2469
Story 1-13	391.087	332.1899	298.3203	381.2979
Story 1-12	348.4865	296.1197	264.9806	340.7259
Story 1-11	306.7082	260.8087	232.5229	300.8083
Story 1-10	266.0676	226.5011	201.1604	261.8379
Story 1-9	226.8931	193.4565	171.1196	224.1314
Story 1-8	189.5373	161.9496	142.6381	188.0247
Story 1-7	154.3711	132.2696	115.9639	153.8726
Story 1-6	121.7812	104.719	91.354	122.0484
Story 1-5	92.1664	79.6143	69.0741	92.945
Story 1-4	65.9342	57.2865	49.397	66.9729
Story 1-3	43.4972	38.0812	32.603	44.5614
Story 1-2	25.2695	22.3616	18.9793	26.162
Story 1-1	11.6642	10.5082	8.8154	12.2516
Story 1	3.1041	2.9181	2.3994	3.3423

Table 2: Story wise displacement of type 2 model

STOREY	T2AUX	T2BUX	T2CUX	T2DUX
Story 1-20	723.8406	520.8793	587.7572	619.1219
Story 1-19	679.4758	486.3515	549.5401	581.8812
Story 1-18	634.186	451.5279	510.9222	543.6996
Story 1-17	588.1431	416.5681	472.1014	504.7251
Story 1-16	541.7327	381.7457	433.4237	465.3003
Story 1-15	495.1849	347.1562	394.9524	425.6303
Story 1-14	448.781	313.0081	356.8988	385.9824
Story 1-13	402.851	279.5312	319.4987	346.6611
Story 1-12	357.7742	246.9694	283.02	307.9947
Story 1-11	313.9539	215.5895	247.7467	270.3259
Story 1-10	271.7042	185.5945	213.9412	233.9564
Story 1-9	231.145	157.0162	181.6168	199.0065
Story 1-8	192.6465	130.1062	151.0603	165.813
Story 1-7	156.6125	105.1305	122.5711	134.7365
Story 1-6	123.4733	82.367	96.4686	106.1597
Story 1-5	93.6865	62.098	73.0839	80.4846
Story 1-4	67.4694	44.4496	52.5898	57.9043
Story 1-3	44.8741	44.8741	34.9671	38.4621
Story 1-2	26.337	26.337	20.5442	22.5353
Story 1-1	12.3276	12.3276	9.6678	10.5256
Story 1	3.3589	3.3589	2.6949	2.8603

5.2 Story drift ratio

The story drift refers to the displacement of one level compared to another that is above or below it. Stories may exhibit different kinds of displacement. Therefore, when the story structure decreases, the probability of the building collapsing is also reduced. The model type two will help in reducing the structure response. The drift ratios for type two B model are less as compare to those of type 2A model. The story drift ratio is reduced in the bottom stories, the ratios become high in middle stories and decreases in the upper stories.

Table 3: Story drift for model type 1

STOREY	T2AUX	T2BUX	T2CUX	T2DUX
Story 1-20	0.011039	0.010316	0.010778	0.011317
Story 1-19	0.011138	0.010429	0.010874	0.011517
Story 1-18	0.011214	0.010517	0.010946	0.011695
Story 1-17	0.011258	0.010572	0.010983	0.011841
Story 1-16	0.011264	0.010586	0.010979	0.011942
Story 1-15	0.011226	0.010551	0.010927	0.011986
Story 1-14	0.011137	0.010459	0.010819	0.011962
Story 1-13	0.010992	0.010306	0.01065	0.01186
Story 1-12	0.010788	0.010089	0.010416	0.011676
Story 1-11	0.010525	0.009802	0.01011	0.011407
Story 1-10	0.010194	0.009441	0.009729	0.011045
Story 1-9	0.009783	0.009002	0.009268	0.010586
Story 1-8	0.009268	0.00848	0.008725	0.010022
Story 1-7	0.008645	0.007872	0.008093	0.009348
Story 1-6	0.007909	0.007173	0.00737	0.008558
Story 1-5	0.007057	0.006379	0.006552	0.007647
Story 1-4	0.006086	0.005487	0.005633	0.006609
Story 1-3	0.004993	0.004491	0.004609	0.005435
Story 1-2	0.003781	0.003387	0.003474	0.004118
Story 1-1	0.002435	0.002169	0.002224	0.002645
Story 1	0.001021	0.000834	0.000856	0.000998

Table 4: Story drift for model type 2

STOREY	T2AUX	T2BUX	T2CUX	T2DUX
Story 1-20	0.012676	0.010395	0.010919	0.011132
Story 1-19	0.01294	0.010517	0.011034	0.011444
Story 1-18	0.013155	0.010592	0.011092	0.011712
Story 1-17	0.01326	0.010578	0.011051	0.011871
Story 1-16	0.013299	0.010534	0.011	0.011968
Story 1-15	0.013258	0.010427	0.010902	0.011986
Story 1-14	0.013123	0.01025	0.010733	0.011913
Story 1-13	0.012879	0.009998	0.010483	0.011741
Story 1-12	0.01252	0.009665	0.010149	0.011466
Story 1-11	0.012071	0.009266	0.009736	0.011094
Story 1-10	0.011588	0.008858	0.009317	0.010686
Story 1-9	0.011	0.00837	0.008814	0.010175
Story 1-8	0.010295	0.007798	0.008223	0.009554
Story 1-7	0.009468	0.007138	0.007539	0.008815
Story 1-6	0.008511	0.006386	0.006759	0.007951
Story 1-5	0.007491	0.005588	0.005927	0.00702
Story 1-4	0.006456	0.004795	0.0051	0.00607

Story 1-3	0.005297	0.003919	0.004177	0.004998
Story 1-2	0.004005	0.002947	0.003153	0.003793
Story 1-1	0.002565	0.001883	0.002023	0.002442
Story 1	0.000961	0.000722	0.000784	0.000925

5.3 Maximum deflection

The deflection in the shear wall model along the periphery is reduced. The column reduces to 33.33% as compared to those model constructed in the L shape shear wall.

5.4 Maximum force in the beams

The earthquake effects at ground story is higher as compared to the middle and top levels. For a given beam the ground storey increases by about 21.21%.

6. Conclusion

The study carried out to show the earthquake response in tall buildings. Different kinds of shear thickness and position have been used. The purpose for the study was to investigate on the whether the location of the shear wall affects its seismic loading. The conclusion that was reached is as follows;

Providing the shear walls at the right location reduce the amount of displacement caused by the earthquakes. Additionally, the percentage of the drift depends on the shear wall thickness location. As such, it is easier to determine the drift ratio.

The model that had shear wall and varying thickness had the highest displacement in the elastic region. Therefore, such a building acts well on the elastic region. There will be no need of looking for a suitable place to construct it than the elastic region.

Upon observation, it was evident that the story drift ratios of the type 2 model were less as compared to the ratios of the type 1 model. The story drift ratio in the bottom storey is very low and it increases in the middle and finally reduces at the upper stories.

7. References

Agrawal. A.S & Charkha S.D. (2012). Effect of change in shear wall location on storey drift of multi-storey residential building subjected to lateral load. *International journal of Engineering Research and Applications*, Volume 2, Issue 3, pp.1786-1793.

Anuj C., (2012). Earthquake Analysis of Building Configuration with Different Position of Shear Wall. *International Journal of Emerging Technology and Advanced*, Volume 2, Issue 12,

ATC, (1996). Seismic Evaluation and Retrofit of Concrete Buildings— Volume 1 (ATC-40). Report No. SSC 96-01. Redwood City (CA): Applied Technology Council;

Bhuia, A.D. & Ramjiyani B.B.,(2011). Solution of shear wall in multi-story building", *International journal of civil and structural engineering,* Volume 2, no.2.

Fintel, M., & Fintel, M. (1995). Performance of buildings with shear walls in earthquakes of the last thirty years. *PCI journal*, *40(3), 62-80*.

Mrugesh D. Shah, Sumant B. Patel ―Nonlinear Static Analysis of R.C.C. Frames (Software Implementation ETABS 9.7)‖ National Conference on Recent Trends in Engineering & Technology.