Defining of Optimum Location of Shear Wall in Setback Building

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Abstract- Irregularly shaped buildings have gained popularity in recent years from aesthetic requirements, limited land area, and the need for natural light and ventilation. Among these, setback buildings are a well-known type of vertical irregularity. These buildings tend to be more susceptible to seismic forces compared to regular buildings. However, by placing shear walls at suitable areas; their susceptibility can be significantly reduced. This study investigates the optimum position of shear walls in setback shape buildings. Four setback shape configurations of G+10 storeys were investigated: setback at Half, setback at two positions, setback on both sides, and setback on all four sides. ETABS analysis software was employed using Response Spectrum Method as per NBC 105:2020. The findings of this study clearly establish the optimum positions for shear walls in setback-type buildings and demonstrate easily how shear walls can simply resist storey displacement and drift when subjected to seismic loading.

Index Terms- Setback shape, Shear wall, Storey displacement, Storey drift, Stiffness

I. INTRODUCTION

Seismic provisions for irregular frame structures have some certain requirements as per the different buildings code for this study NBC: 105:2020 is used. Irregularity in building frames are two types, namely, horizontal and vertical irregularities. Vertical irregularity includes the geometrical irregularity, weak storey, soft storey, mass irregularity and stiffness irregularity, SEISMIC DESIGN OF BUILDINGS IN NEPAL, 2020.

At the present time, constructing a structure with all the standard configurations is not practical in most cases because of the irregular plot dimensions, as well as the aesthetic and functional needs in urban areas. Structures that have more irregular shapes either horizontally or vertically are more prone to damage during earthquakes, Divya & Murali, 2022. Vertical geometrical irregularity (setback) is the one of the vertical irregularity which we see in the urban areas. Setbacks in the building are provided not only for the aesthetic reason, but also for complying with the floor area ratio as per building byelaws restriction. Setback is provided, where there is space constraints and closer proximity of the building is required and also for the light for visual, Bhatta et al., 2021. Such setback buildings are very sensitive to earthquake which can be prevented by providing shear wall in optimum position of building. Shear walls are structural elements which resist the effect of two things; they are a) in plane shear and b) in plane bending action due to moment from shear. Also along with these, the shear wall, as a structural functional unit, tends also to resist in plane shear in vertical direction (as a direct consequence to shear in the horizontal direction) and the buckling effect of dead loads coming from top Sree & Priya, 2021. By providing shear wall in right position in the irregular building makes building stable and gives better seismic performance during Earthquake and lateral force.

The location of shear wall determines the efficiency of the shear wall. If torsional force increased due to location of the shear wall, it becomes biggest enemy of the building. Thus the shear wall has to place where center of mass and center of stiffness should be close et al., 2020.

Shear walls play a very crucial role in resisting seismic and lateral loads, and their thickness, position, and shape play a vital role in determining the performance of a building. Their placement at strategic locations, i.e., at corners or around the core in the form of a U-shape, minimizes displacement and story drift to a great extent. Studies have shown symmetrical corner location of shear walls gives the best performance in terms of period, frequency, shear, displacement, and drift. Avoidance is necessary, however, since setbacks in story height can improve inter-story drift—especially at mid-levels. Shear wall curtailment also should be avoided, particularly in those structures which are required to be safe when subjected to extreme earthquakes Suwal & Khawas, 2022.

II. LITERATURE REVIEW

1. Chavhan, 2015 conducted a study on "Vertical Irregularities in RC Building Controlled By Finding Exact Position of Shear Wall," using Response Spectrum Analysis method. Results were compared between the torque and shear force on each floor. It was found that an enhancement in the eccentricity between geometrical center of building and center of mass increases the twisting in building. The torsional value of structure with shear wall at lift was much greater (for EQX) than without shear walls, which increased the eccentricity in both directions. Two shear walls parallel to X- axis didn’t show the good results for EQX and EQY. However, two shear walls parallel to Y- axis give best result for EQX.
2. Student, 2018 conducted a study on "Seismic Analysis of Shear Wall at Different Location on Multi-story RCC Building," using Response Spectrum Analysis method. The results were based on seismic parameters like displacement, axial force, bending moment and base shear. It was found that maximum lateral displacement increased as the story height increased and also time period increased as the model frequency increased. Due to the presence of a shear wall at the center of model 4, the minimum lateral displacement of building was reduced compare to all models. The maximum base shear was observed in model 4 in both X and Y-directions and minimum moment was observed for model 4 compared to other models. The maximum axial force was found to be in model 2 and the maximum shear force and moment were found in model 1 compared to all models. In types 2, 3 and 4 the maximum displacements were reduced to 40 to 50%, the maximum base shear was reduced to 10 to 20% and the maximum shear force was reduced by 30 to 50% as that of bare frame type. Hence the building with type 3 shear wall was more efficient.
3. Shahrooz & Moehle, 1990 conducted an experimental and Analytical study on "Seismic Response and Design of Setback Buildings," taking 6th storey building with a setback. It was found that both the conventional static and conventional dynamic design methods were found inadequate to prevent concentration of damage in members near the setback for certain configurations. Some building code defined effectively irregular setback buildings as those having either 33% reduction in floor mass at the setback or 25% reduction in plan dimension at the setback, the analysis of fame having various setbacks and designed by both static and dynamic method showed that simple definition was not appropriate. For setback structures, design should impose increased strength on tower and relative to the base. The static analysis method proposed that amplifies design forces and improves behavior of the tower.
4. Rana & Raheem, 2015 conducted a study on "Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building". It was found that the setback was directly proportional to the critical shear force i.e. setback increased, the critical shear force also increased. The regular building showed very low shear force than the setback frame. For all building height critical bending moment was found more in irregular frame than the regular frame. The regular frame was found better in seismic performance than the irregular frame. Less % of reduction in floor area was found superior than other, among setback frame.

III. OBJECTIVES OF STUDY

The aim of this research is to defining the optimum position of shear wall in setback building.

IV. DIMENSIONS AND MODELS

The buildings modeled for this study feature G+10 storey buildings with 9x9 bay having 27m and 27m in X and Y direction respectively, other details are given in the table below.

Parameters	Details
Type of the structure	Multi-story RC building
No of storey	G+10
Typical story height	3m
Shape of building	setbacks
Grade of concrete	M25
Rebar grade	Fe 500
Column size	800x800mm
Beam size	650x750mm
Slab thickness	125mm
Wall Thickness	Ext-230mm, Int-115mm
Thickness of shear wall	230mm
Importance factor	1
Seismic zone	V

Seismic zone factor (Z)	0.35
Damping ratio	5%
Soil type	Medium Soil
LL, floor	3 kN/m2
LL, roof	1.5 kN/m2
Floor finish	1 kN/m2

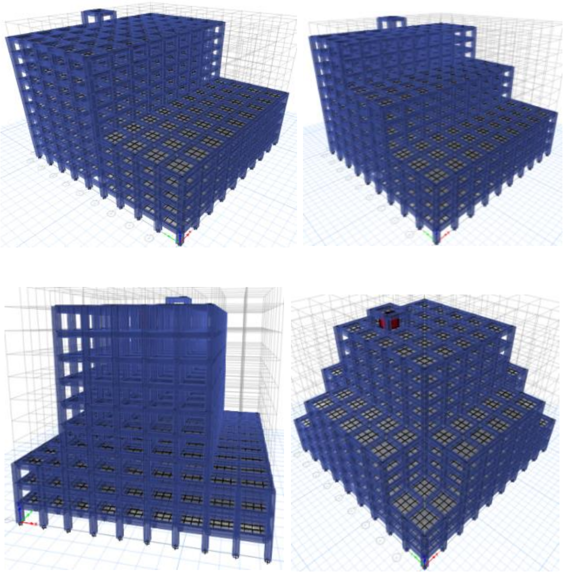

Figure 1. Different types of selected setback shapes are setback at half, setback at 2 positions, setback at both sides and setback at four sides respectively.

V. METHODOLOGY

This study is based on the structural modelling and simulation using ETABS software. The four different configuration setback building models were considered: (i) setback at half, (ii) setback at 2 positions, (iii) setback at both sides and (iv) setback at four sides. Initially, these setback models were analysed using the Response Spectrum Method as per NBC: 105:2020 in order to evaluate their seismic performance and determine whether they were safe or not. Lastly each of the four setback configurations was modelled with the shear walls located in different positions: (i) along X-axis, (ii) along Y-axis, (iii) at corners and (iv) at periphery. This provided total of 16 models. These models were re-analyzed using the Response Spectrum Method to obtain seismic performance and best shear wall location for minimising strorey displacement and drift in setback-shaped buildings.

VI. RESULTS AND DISCUSSIONS

Results from the Response Spectrum analysis of four setback shape buildings with shear wall at four positions are as flows.

6.1 Seismic Parameters Results of setback at half due to RSA, ULS

6.1.1 Maximum Storey Displacement

From the figure 2 maximum storey displacement in X-direction is reduced by type 4(64.14%) >type1 (38%)> type 2 (33.32%)> type 3 (-0.93%), similarly from figure 3 displacement in Y-direction is reduced by type 4 (53.75%)>type 3 (52.64%)> type 1 (39.17%)> type 2 (0.02%). Maximum displacement reduced by the type 1 in both direction than type2, type3 and type4.

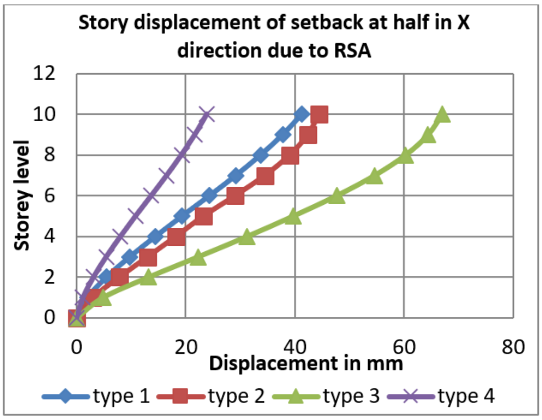

Figure 2 storey displacement of setback at half in X-direction due to RSA.

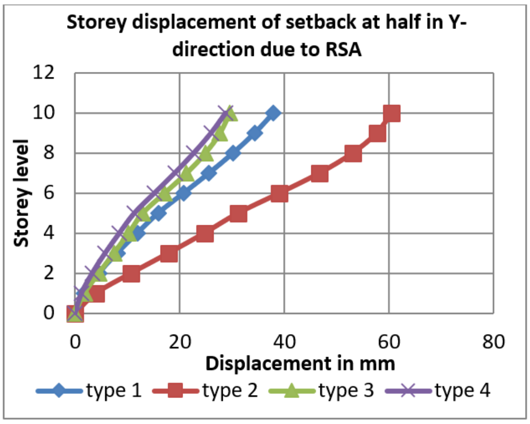

Figure 3Storey displacement of setback at half in Y-direction due to RSA.

6.1.2. Maximum Storey Drift

From the figure 4 maximum storey drift in X-direction is reduced by type 4(68.13%) >type1 (44.40%)> type 2 (36.04%)> type 3 (-0.95%), similarly from figure 5 Drift in Y-direction is reduced by type 3 (80.92%)>type 4 (53.45%)> type 1 (41.35%)> type 2 (-1.48%). Maximum drift reduced by the type 4 in X- direction and type 3 in y -direction. in both the directions type 4 reduced storey drift in sufficient way.

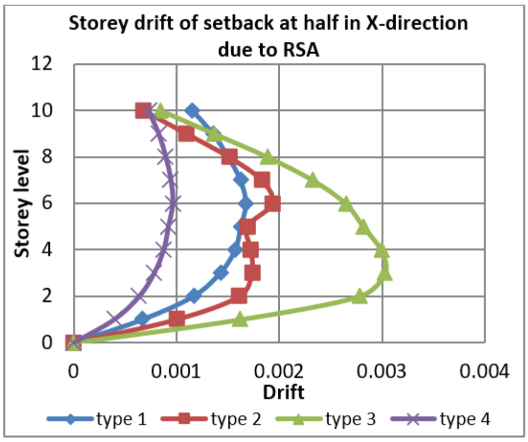

Figure 4 storey drift of set back at half in X-direction due to RSA

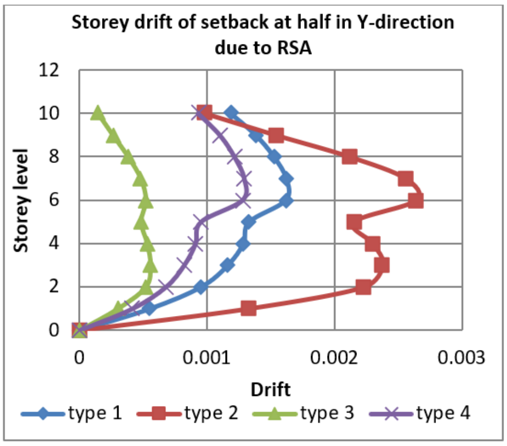

Figure 5storey drift of set back at half in Y-direction due to RSA

6.1.3. Maximum storey stiffness

From the figure 6 maximum storey stiffness in X-direction are type 4 >type2 > type 1> type 3, similarly from figure 7 stiffness in Y-direction are type 3>type 4 > type 1> type 2. Maximum storey stiffness type 4 in X- direction and type 3 in y -direction. in both the directions type 4 shows the sufficient stiffness than other type of building.

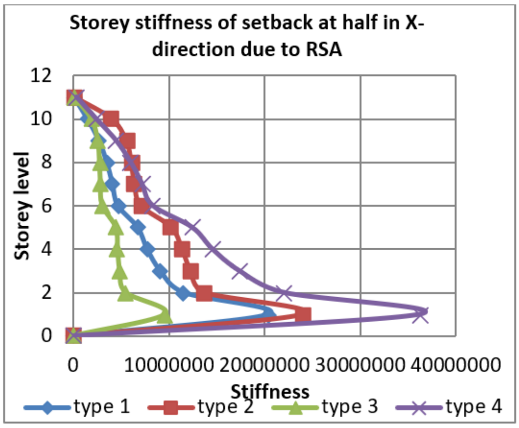

Figure 6 stiffness of setback at half in X- direction due to RSA

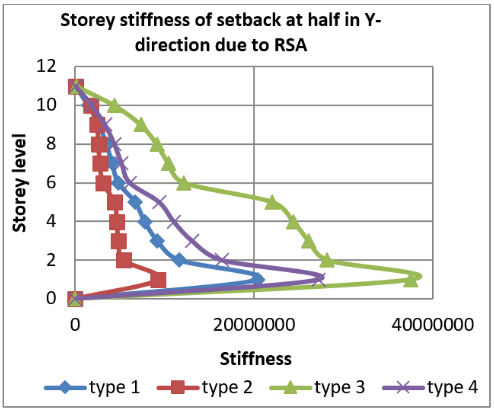

Figure 7stiffness of setback at half in Y- direction due to RSA

6.2 Seismic Parameters Results of setback at 2 positions due to RSA, ULS

6.2.1. Maximum storey displacement

From the figure 8 maximum storey displacement in X-direction is reduced by type 8(68.02%) >type6 (67.45%)> type 5 (43.53%)> type 7(-0.33%), similarly from figure 9 displacement in Y-direction is reduced by type 7 (51.13%)>type 5(47.30%)> type 8 (36.96%)> type 6 (0.01%). Maximum displacement reduced by the type 8 in X-direction and type 7 in y direction. Type 8 shows sufficient reduction of displacement in both directions.

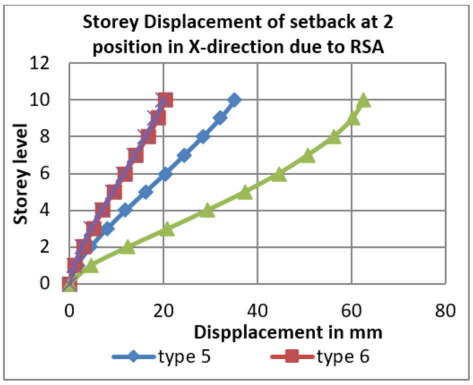

Figure 8 storey diaplacement of setback at 2 position in X-directio due to RSA

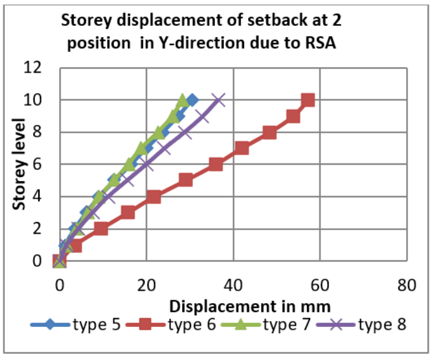

Figure 9 storey diaplacement of setback at 2 position in Y-directio due to RSA

6.2.2. Maximum storey drift

From the figure 10 maximum storey drift in X-direction is reduced by type 8 (71.96%) >type 6 (70.23%)> type 5 (50.52%)> type 7 (-0.21%), similarly from figure 11 Drift in Y-direction is reduced by type 5 (47.16%)>type 7 (45.9%)> type 8 (35.64%)> type 6 (-0.13%). Maximum drift reduced by the type8 in X- direction and type 5 in y -direction. In both the directions type 8 reduced storey drift in sufficient way.

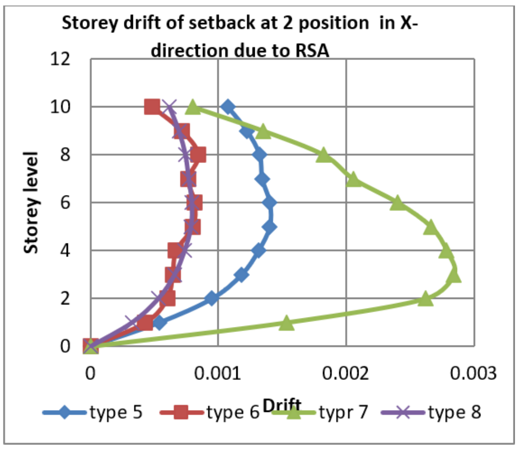

Figure 10storey drift of setback at 2 positions in X-direction due RSA

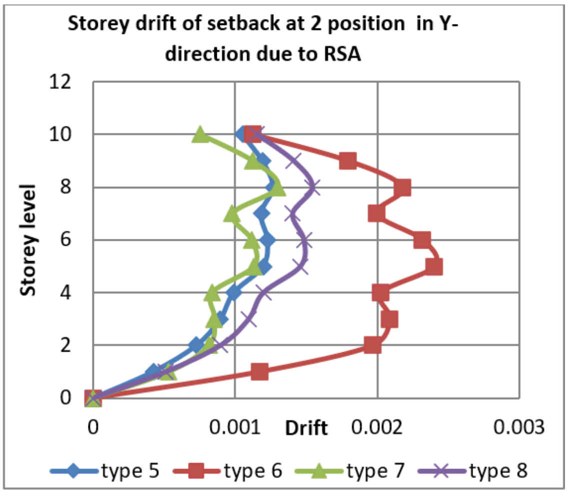

Figure 11 storey drift of setback at 2 positions in Y-direction due RSA

6.2.3. Maximum storey stiffness

From the figure 12 maximum storey stiffness in X-direction are type 6 >type8 > type 5> type 7, similarly from figure 13 stiffness in Y-direction are type 7>type 5> type 8> type 6. Maximum storey stiffness type 6 in X- direction and type 7 in y -direction. In both the directions type 8 shows the sufficient stiffness than other type of building.

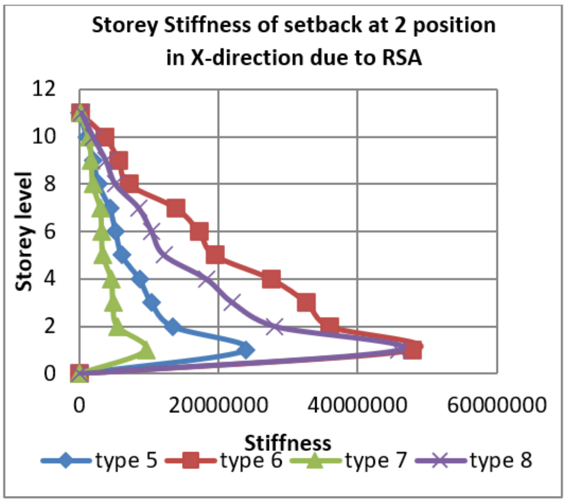

Figure 12 Storey stiffness of set back at 2 positions in X-direction due to RSA

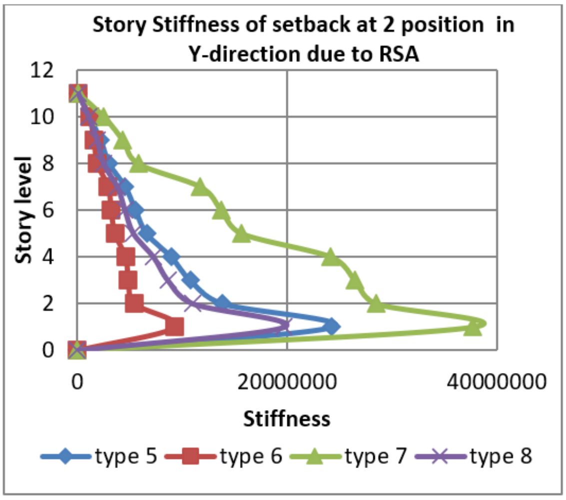

Figure 13Storey stiffness of set back at 2 positions in Y-direction due to RSA

6.3 Seismic Parameters Results of setback at both sides due to RSA, ULS

6.3.1 Maximum storey displacement
From the figure 14 maximum storey displacement in X-direction is reduced by type 10 (51.21%) >type 9 (42.32%)> type 12 (36.45%)> type 11(-0.2%), similarly from figure 15 displacement in Y-direction is reduced by type 11 (68.70%)>type 12 (64.34%)> type 9 (39.06%)> type 11 (-0.68%). Maximum displacement reduced by the type 10 in X-direction and type 11 in y direction. Type 9 and 12 shows sufficient reduction of displacement in both directions.

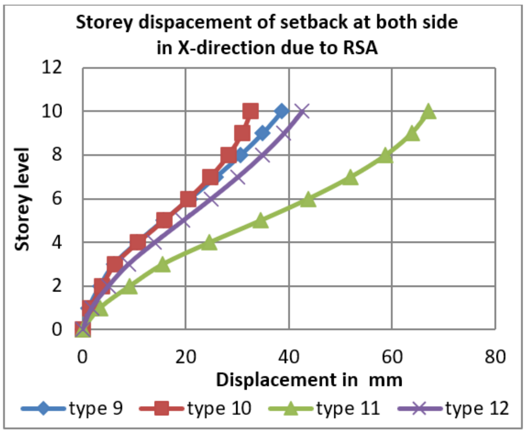

Figure 14 storey displacement of setback at both sides in X-direction due to RSA

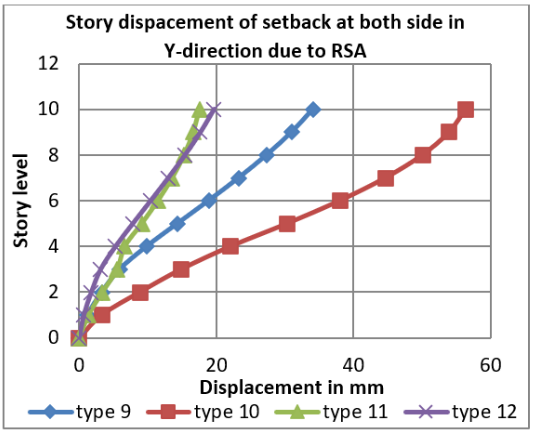

Figure 15storey displacement of setback at both sides in Y-direction due to RSA

6.3.2. Maximum storey drift
From the figure 16 maximum storey drift in X-direction is reduced by type 10 (49.21%) >type 9 (48.65%)> type 12 (44.33%)> type 11 (0.09%), similarly from figure 17 Drift in Y-direction is reduced by type 11 (69.64%)>type 12 (68.65%)> type 9 (44.45%)> type 10 (-0.73%). Maximum drift reduced by the type 10 in X- direction and type 11 in y -direction. In both the directions type 9 and 12 reduced storey drift in sufficient way.

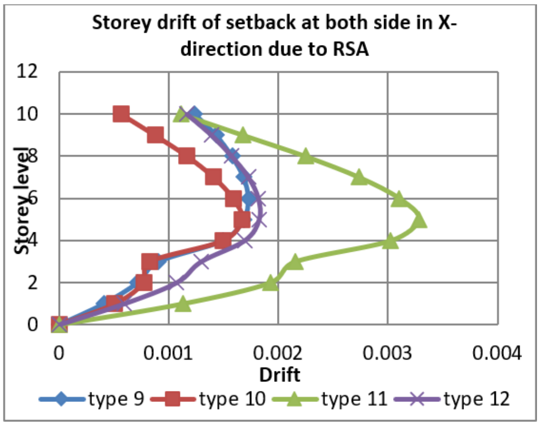

Figure 16 storey drift of setback at both sides in X-direction due to RSA

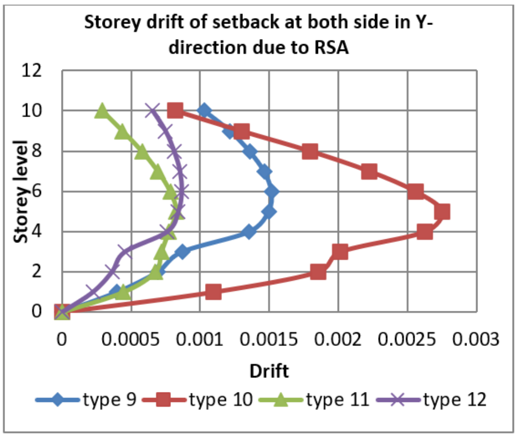

Figure 17 storey drift of setback at both sides in Y-direction due to RSA

6.3.3 Maximum storey stiffness

From the figure 18 maximum storey stiffness in X-direction are type 10 >type9 > type 12> type 11, similarly from figure 19 stiffness in Y-direction are type 12>type 11> type 9> type 10. Maximum storey stiffness type 10 in X- direction and type 12 in y -direction. In both the directions type 9 shows the sufficient stiffness than other type of buildings.

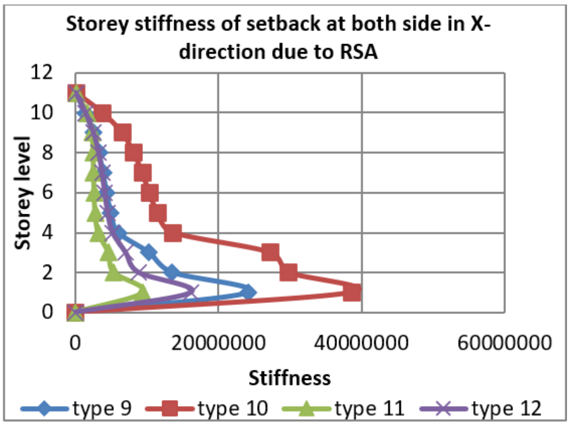

Figure 18 Storey stiffness of setback at both sides in X-direction due to RSA

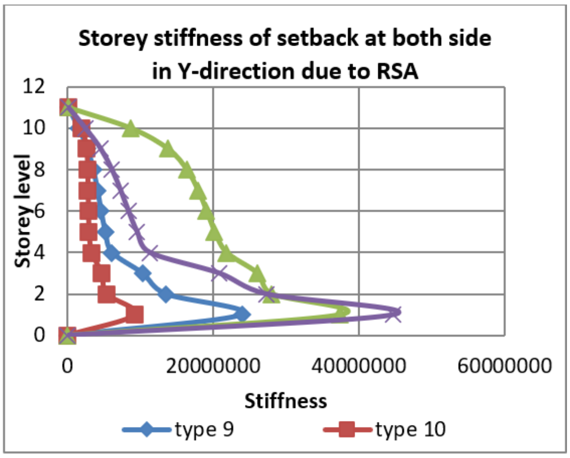

Figure 19 Storey stiffness of setback at both sides in Y-direction due to RSA

6.4 Seismic Parameters Results of setback at four sides due to RSA, ULS

6.4.1 Maximum strorey displacement

From the figure 20 maximum storey displacement in X-direction is reduced by type 16 (70.39%) > type 14 (64.63%)> type 13 (53.51%) > type 15 (0.5%), similarly from figure 21 displacement in Y-direction is reduced by type 16 (73.23%) > type 15 (62.98%) > type 13 (53.66%) > type 14 (0.07%). Maximum displacement reduced by the type 16 in both directions.

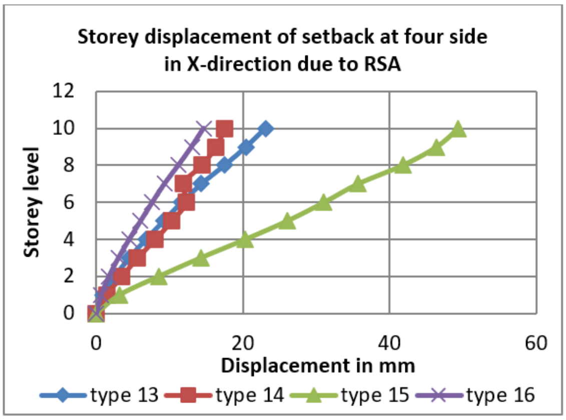

Figure 20 storey displacement of setback at four sides in X-direction due to RSA

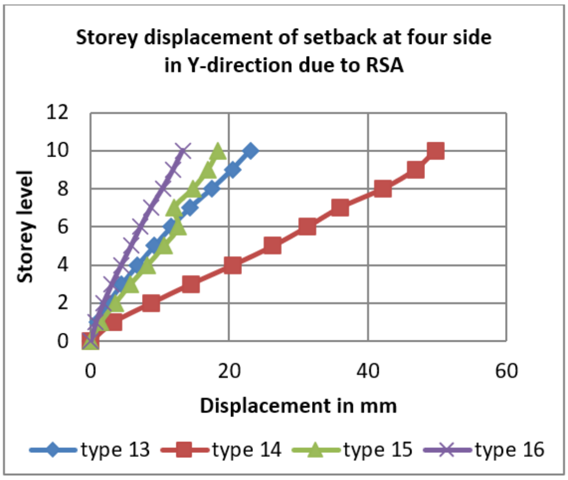

Figure 21 storey displacement of setback at four sides in Y-direction due to RSA

6.4.2 Maximum storey drift
From the figure 22 maximum storey drift in X-direction is reduced by type 16 (64.40%) > type 14 (57.10%) > type 13 (48.48%) > type 15 (-4.8%), similarly from figure 23 Drift in Y-direction is reduced by type 16 (72.91%) > type 15 (58.18%) > type 13 (50.98%) > type 14 (-0.8%). Maximum drift reduced by the type 16 in both directions.

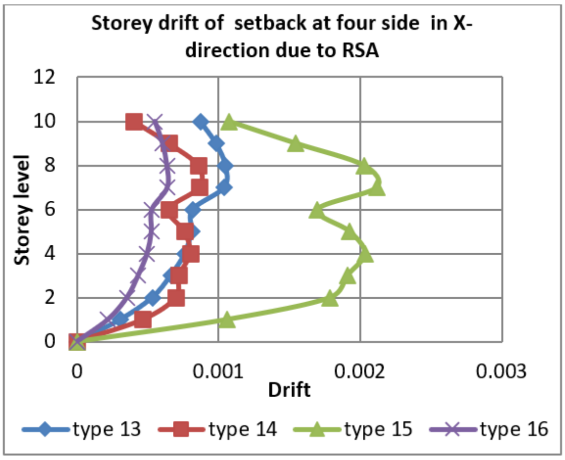

Figure 22 storey drift of setback at four sides in X-direction due to RSA

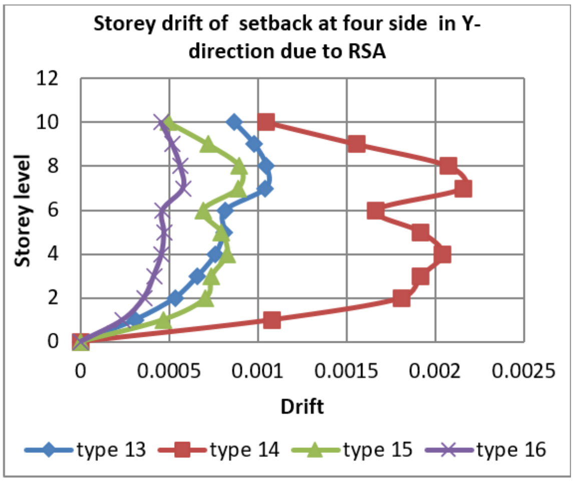

Figure 23storey drift of setback at four sides in Y-direction due to RSA

6.4.3 Maximum storey stiffness
From the figure 24 maximum storey stiffness in X-direction are type 16 > type 14 > type 13 > type 15, similarly from figure 25 stiffness in Y-direction are type 16 > type 15> type 13 > type 14. Maximum storey stiffness type 16 in both directions.

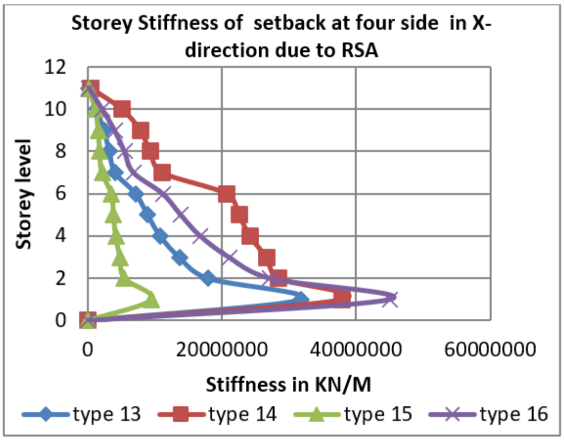

Figure 24 storey stiffness of setback at four sides in X-direction due to RSA

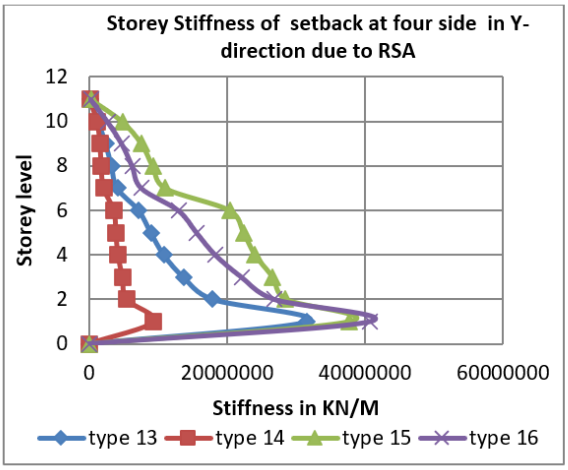

Figure 25 storey stiffness of setback at four sides in Y-direction due to RSA

In this study 16 models are used which are, Setback at half building with shear wall at corner (type1), along X-axis (type2), along Y-axis (type3) and at periphery (type4), setback at 2 positions with shear wall at corner (type5), along X-axis (type6), along Y-axis(type7), at periphery (type8), setback at both sides with shear wall at corner (type9) along X-axis (type10), along Y-axis(type11), at periphery (type12) and setback at four sides with shear wall at corner (type13) along X-axis (type14), along Y-axis(type15), at periphery (type16). After the analysis of 16 models using RSA results showed that shear wall along X-axis reduced displacement, drift and increased stiffness along X-direction only similarly shear wall along Y-axis reduced displacement, drift and increased stiffness along Y-direction only. This shows that shear wall along X-axis provide more stiffness along X-direction and counteract lateral force along X-direction only and vice versa. Type 4 reduced displacement and drift more than Type1, type2 and type3 in both directions, similarly increased stiffness. Type 8 reduced displacement and drifts more than Type5, type6 and type7 in X-direction and type 5 in Y-direction, similarly type 8 increased the stiffness more than type 5 in X-direction and vice versa, over all type8 reduced displacement, drift and increased stiffness in both directions. Type 9 reduced displacement, drifts and increased stiffness more than type12 in X- direction and Type 12 in Y- direction but in both directions Type 9 performed better than type12. Type 16 reduced displacement, drifts and increased stiffness more than type13, type14 and type 15.

CONCLUSION

1. The location of the shear walls plays a significant role in optimizing structure performance under lateral loads. Shear walls along the X-axis mostly improved stiffness and reduced displacement and drift along the X-direction, and those along the Y-axis were effective along the Y-direction. This confirms that shear walls provide stiffness and resistance mainly along the direction of installation.
2. Of the various configurations, Type 4 was more effective than Types 1, 2, and 3, while Type 8 was more effective than Types 5, 6, and 7 in the X-direction and even more effective than Type 5 in the Y-direction. Significantly, Type 8 reduced displacements and drifts in a consistent manner and improved stiffness in both directions, making it one of the most efficient layouts. Similarly, Type 9 performed better than Type 12 in both directions, and Type 16 performed better than Types 13, 14, and 15.
3. It can be said that proper location and configuration of shear walls have influences on the structure response. Structure like Type 4, Type 8, Type 9 and Type 16 performed better and it has been reaffirmed that optimum location of shear walls guarantees reduced displacement and drift and maximum stiffness in either direction, thereby enhancing seismic performance of the structure.

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