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Performance Analysis of Multi-Storey RCC Building with Shear Wall

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Abstract—*Earthquake causes lateral forces in the building, due to their inertia. A large number of structural systems have been developed to resist the gravitational and lateral loads. Shear-wall and frame Shear-wall are quite common for multi-storey buildings. The performance of the shear wall building during past earthquakes has been observed to be quite satisfactory. In this work, a numerical study has been made to investigate the effect of shear wall introduction in the RC-frame, by comparing the different results for the building designed as per Indian Codes for different location of shear wall in the frame and frame without shear-wall (when shear-wall is designed by different methods) & also, a study has been made to know the behavior of non-linear layered shear-wall when it is in the structure and without the structure and its performance point is estimated.*

1. INTRODUCTION

A building structure is primarily subjected to gravity and lateral loads. Gravity loads acting on the building consists the self-weight of the member plus live loads acting on the members. The lateral forces on the structure caused by wind, blast or earthquake and magnitudes of such forces are controlled by the intensity of these agents. The structure should have adequate strength, stiffness and ductility so they can respond satisfactorily to these occasional loads.

A wall that is subjected to lateral load in its plane is referred as ”shear wall”. It enhance the strength, stiffness and ductility of the frame. The term shear wall is actually a misnomer as far as high rise building is concerned. Shear walls are designed to resist the lateral load induced by wind or EQ. They may be of any shape like rectangle, angle, channel etc.

In frame shear wall, lateral load resistance is provided by combine contribution of frame and shear wall, this system generally called “Dual system”. Under the action of lateral load frame primarily deform in a shear mode, whereas wall behave like a vertical cantilever with primarily flexure deformation. It is found that the walls and frames share in resistance of storey shear forces in the lower stories, but tend to oppose each other at higher levels. The mode of sharing resistance to lateral loads between walls and frames of dual system in strongly influenced by dynamics response characteristics and developed of plastic hinges during EQ, and it may be quite different from that predicted by an elastic analysis.

A large number of models are available for analytical modeling of shear-walls [1-3]. The shear-walls can be modeled using wide-column analogy, braced frame analogy, plane stress element and shell element. In the present study, the wide-column analogy and sell-element method are use for linear analysis and comparing the effect of shear wall introduction in the building, while Shell-element model is use for non-linear shear-wall for non-linear analysis. The buildings are designed as per Indian Standards using SAP 2000 v 14.2.4 software. The non-linear behavior and performance of only shear wall (not in frame) is studied by Non-linear Static Analysis and Non-Linear Dynamic Analysis while performance of buildings with shear-wall is studied using Non-Linear Static Analysis (Push-over Analysis) [4-7].

2. EVALUATION OF PERFORMANCE POINT OF ONLY SHEAR WALL BY PUSH-OVER ANALYSIS AND TIME HISTORY ANALYSIS

General information about the shear wall (Fig. 1):

Width of the wall = 4m

Thickness = 250 mm

Height = 28.5m

Grade of concrete and steel = M30 and Fe-415 respectively.

Earthquake zone = IV

Importance factor =1

Only dead load of wall is taken in the analysis & wall is modeled by using layered non-linear shell element.

Result of Push-over Analysis (Fig. 2)

Time period = 1.24 sec (X-direction) and 1.74 sec (Y-direction)

Base Shear = 35.41 kN

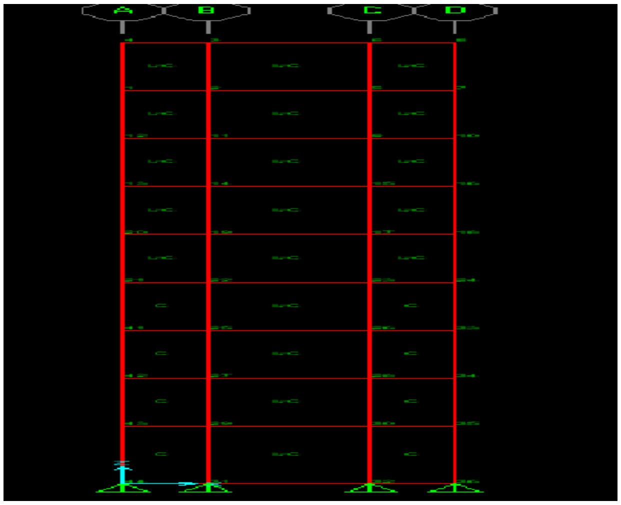

Fig. 1: Model of shear wall use for analysis

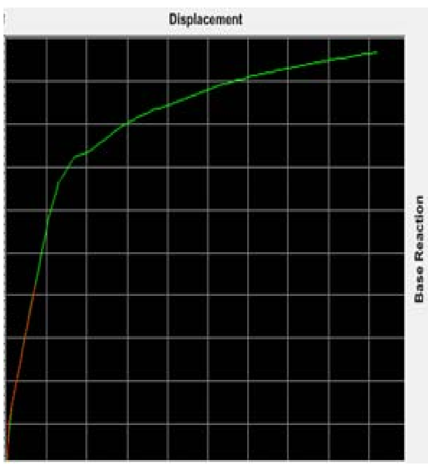

Fig. 2: Capacity curve of only shear wall

Result of time-history analysis:

Time-history analysis of "Only Shear Wall" is carried out by using the Time-history data of 40 sec IS-1893 earthquake (Fig. 3, 4 and 5).

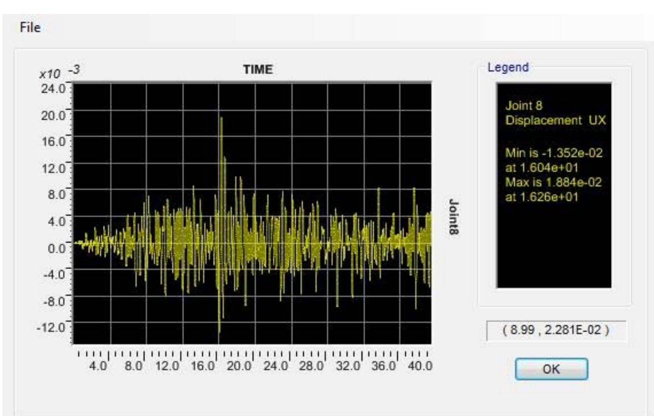

Fig. 3: Time v/s displacement plot

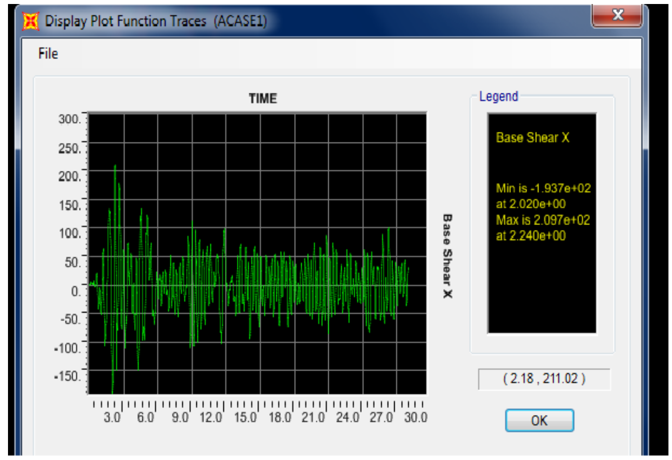

Fig. 4: Time v/s Base shear plot

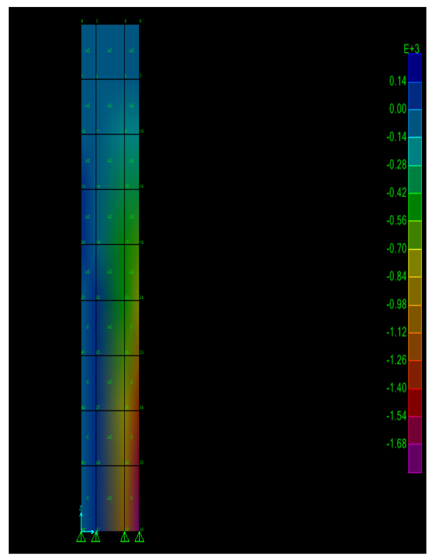

Fig. 5: Stress-Distribution in the wall

1-After 4.41sec of Earthquake maximum displacement in the wall occur and it is 13 mm.

2-After 2.24 sec maximum base-shear in X-direction is 209.7 kN.

Manual calculation for target displacement of only shear wall (layered shell shear wall) according to ASCE-41

Time period= 1.24 sec

Weight (W) = 35.41 kN

Vy (From Capacity curve) =794.64 kN

Now,

(Sa/g)= (1.36/T) *Z

= (1.36/1.24) * 0.24

=0.2632

And, Ra= (0.2632*35.41)/(794.64)

= 0.0117

C2 = 1

C1 =1

By putting these values in target displacement equation of ASCE-41

We get, target displacement = 130.73 mm

3. NUMERICAL STUDIES AND RESULTS

Here, In this study Analysis on linear and Non-linear building models is done.

Linear Modeling and analysis

The building used for the study purpose includes:

Artificially generated G+10 storey frame structure.

A (G+10) storey RC building with shear walls located at the periphery of the building. It consist shear wall fully symmetric in longitudinal as well as in transverse direction.

A (G +10) storey RC building with shear walls located at the periphery and also as the core. It consist shear wall (provided at periphery) fully symmetric in longitudinal as well as transverse direction, while central core shear wall is un-symmetrical in longitudinal direction but symmetrical in the transverse direction.

Loading consideration

Dead load(DL) and Live load (LL) have been taken as per IS-875 (part-I) and IS:875 (part-II) resp. Seismic load calculation has been done based on IS:1893-2002.

Load combination considered in the analysis:

1.5 (DL+LL)

1.5 (DL –LL)

1.2 (DL +LL +EQ)

1.2 (DL +LL –EQ)

1.5 (DL+ EQ)

1.5 (DL-EQ)

0.9 DL + 1.5 EQ

0.9 DL – 1.5 EQ

The modeling of the RC frame, RC frame with shear wall at the periphery and RC frame with shear wall and the core with parameters discussed above is done in SAP 2000 v 14.2.4 . The floor diaphragm is assumed to be rigid in its own plane. For the modeling of shear wall and shear wall core wide column model and shell element model is used.

Result of linear analysis

1- Shear wall reduces the time period of vibration. Here in linear analysis period of vibration of RC frame comes out 2.27 sec , which get reduce by 32.37% when shear wall is provided at the periphery and becomes 1.535 sec, and the time period further reduces by 19.67% when shear core wall is also introduced.

2-Here,In this work shear wall is modeled by two methods i.e WCA and SEM both gives approximately the same period of vibration with a minor variation of 8.41%.

3-Shear wall increases the BASE SHEAR of the structure . Base shear comes out approximately same when shear wall is modeled either by WCA or SEM .Here in our observation a small variation of 2.25% comes out in both the methods for the case when shear wall is provided at the periphery , and a variation of 2.09% for the case when shear core is also provided.

4-Shear wall reduces the deflection. Here, from the top storey deflection in lateral direction we conclude that shear wall when provided at the periphery reduces the deflection by 52.25% and the deflection further reduces by 21.45% when shear core wall is also provided.

Non-linear modeling and analysis:

8.2.1- Parameter of the building

The building used for the study purpose includes:

Artificially generated G+9 storey frame structure .

A (G+9) storey RC building with shear walls located at the periphery of the building. It consist shear wall fully symmetric in longitudinal as well as in transverse direction .

A (G +9) storey RC building with shear walls located at the core. It consist central core shear wall which is un-symmetrical in longitudinal direction but symmetrical in the transverse direction.

Dead load(DL) and Live load (LL) have been taken as per IS-875 (part-I) and IS:875 (part-II) resp. Seismic load calculation has been done based on IS:1893-2002.

After designing the building using the linear analysis, non-linear modeling of the building is done in SAP2000 v 14.2.4, using non-linear properties for the beams, column, and shear walls. In order to define non-linear properties to beams, column and shear walls deformation controlled M3 and P-M2-M3 hinges are assigned. Non-linear shear-wall is modeled by using layered shell elements. Two types of shell elements are defined one with confined concrete and other with un-confined concrete. In confined shell element 3% of steel is provided while in unconfined shell element 0.3% of steel is provided

For modeling of the shear wall using non-linear layered shell element no modifier has been assigned so that the stiffness of the structure obtain is slightly higher while modeling the wall using shell element. The period of vibration obtained using shell element is higher than wide column model since structure becomes more flexible when we are not applying modifier to the wall section.

4. NON-LINEAR STATIC ANALYSIS

To check the performance of the shear wall and shear core wall building non-linear static analysis is performed using SAP. Push-over analysis is relatively simple and easy to perform. It considers the non-linear behavior of the structure but it is an approximate method of analysis in which the structure is subjected to increasing lateral load with a varying height wise distribution, until a desired displacement is reached. Then a lateral load pattern proportional to mode shape is distributed along the height of the building is applied. The lateral load is increasing until some members yield. The structural model is modified to account for the reduced stiffness of the yielded members and lateral forces are again increased until some member yield. This procedure is repeated until structure becomes a mechanism or fails due to P-delta effect. The hinge pattern when shear wall at periphery is shown below (Fig. 6). Finally the push-over curve is plotted as base shear versus roof displacement (Fig. 7).

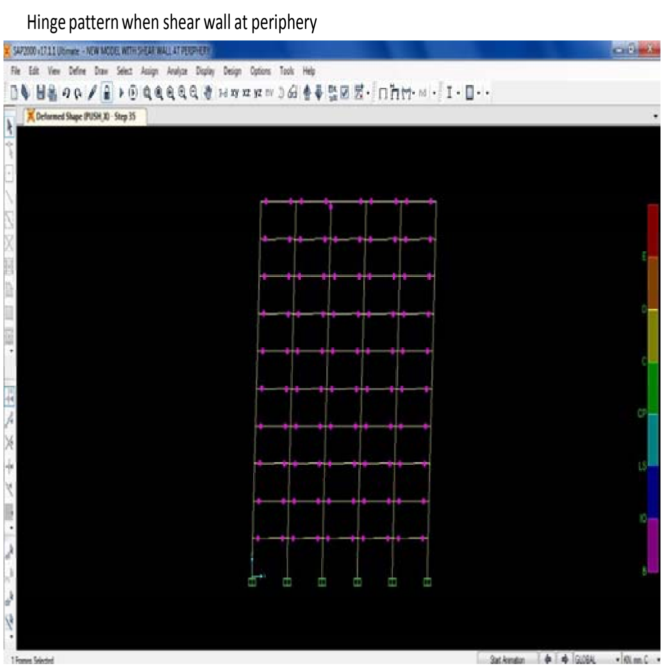

Fig. 6: Hinge pattern when shear wall at periphery

Calculation of target displacement:

Te = 1.1396sec

Here, Te > 1

C1 =C2 =1

Fig. 7: Capacity curve of shear wall building having shear wall at periphery

As, Co depends upon the height of the building , from table its value is 1.3

Sa = (1.36/1.1396) *0.24

=0.2864

Now by using the equation of ASCE-41

Target displacement = 120.15mm

Shear wall at core (Fig. 8):

Calculation of target displacement

Te = 1.002sec

Here, Te > 1

C1 =C2 =1

As, Co depends upon the height of the building , from table it's value is 1.3

Sa = (1.36/1.002) *0.24

=0.32574

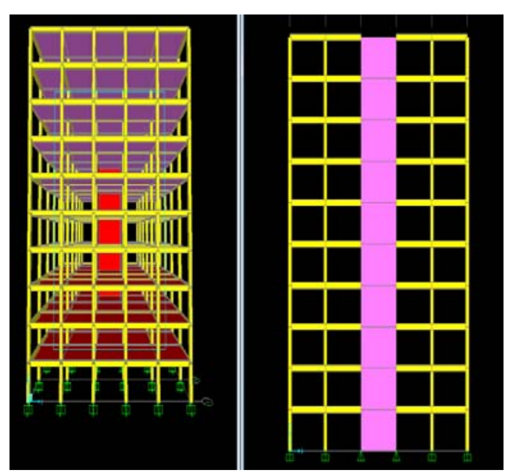

Fig. 8: 3-D model of RC frame with shear wall at core

Now by using the equation of ASCE-41

Target displacement = 105.56mm

Target displacement calculated for RC-frame by ASCE-41,when shear wall is at core comes out 105.56mm (Fig. 9, 10), while the target displacement for the same frame when shear wall is periphery comes out 120.15 mm.

Building undergo more displacement when shear wall is at periphery, So the suggested location is at periphery.

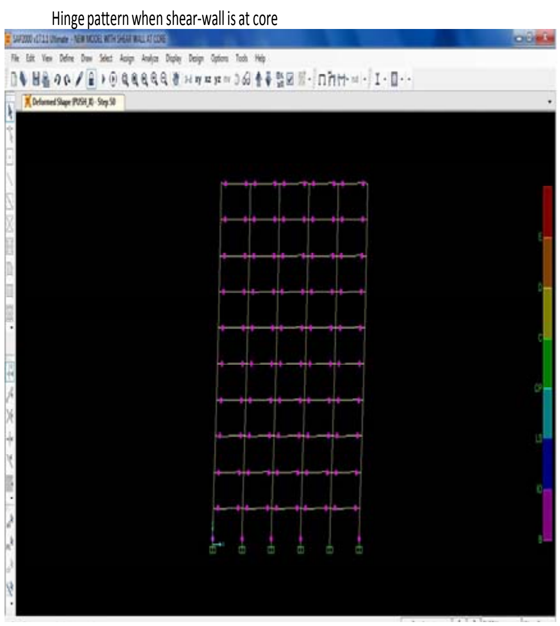

Fig. 9: Hinge pattern in frame when shear wall is at core.

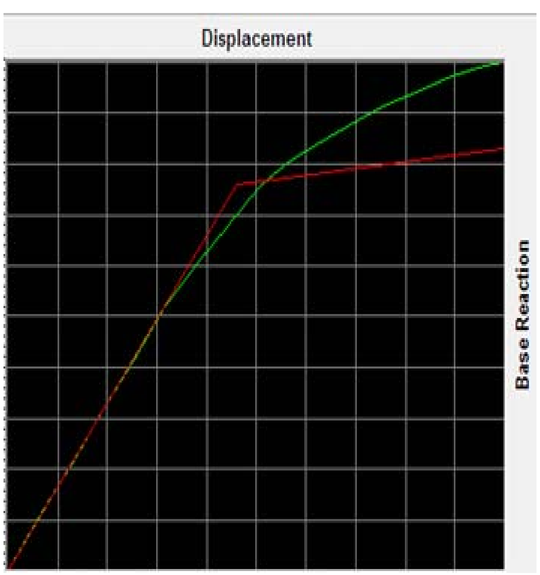

Fig. 10: Capacity Curve of shear core wall building in longitudinal direction

5. CONCLUSIONS

The behavior of RC-Frame, Frame with Shear wall at periphery and Frame-shear core wall buildings under seismic loading has been studied in this Dissertation. First the effect of shear wall introduction in RC-frame has been studied analytically by comparing the results of Linear-analysis of frame, frame with shear wall at periphery and shear wall at core (modeled by both wide column and shell element respectively). Secondly, the performance analysis of Non-linear shear wall has been done (only shear wall not in Frame) and its target displacement is obtain by Push-over analysis and also its performance in direct EQ has been studied by doing Time-History analysis of wall by using 40sec EQ data of IS-1893. The third step consisted the evaluation of performance point (target displacement) of RC-frame building for different location of non-linear shear-wall by using non-linear static analysis (Push-over analysis) and suggest the suitable location of shear wall.

Following are the main conclusion of the study:

1-Shear wall reduces the time period of vibration. Here in linear analysis period of vibration of RC frame comes out 2,27sec , which get reduced by 32.37% when shear-wall is introduced at the periphery and become 1.535sec ,and the time period further reduced by 19.67% when shear-wall core wall is also introduced.

2-Here, in this dissertation work, shear-wall is modeled by two methods i.e., WCA & SEM, both gives approximately the same period of vibration with a minor variation of 8.41%. Wide column model under estimate the ductility capacity. While shell element model over-estimate the ductility capacity.

3-shear wall increases the BASE-SHEAR of the structure. Base shear comes out approximately same where shear-wall is modeled either by WCA or SEM. Here in our observation a small variation of 2.25% comes in both the methods for the cases when shear wall is provided at the periphery, and variation of 2.09% for the case when shear wall at core is also provided.

4-Shear wall reduced the deflection, here, from the top storey deflection in lateral direction we conclude that shear wall when provided at the periphery reduces the deflection by 52.25% and the deflection further reduced by 21.45% when shear core wall is also introduced.

5-In push over analysis of ONLY SHEA-WALL (wall not in Frame)no hinge formed and wall remain safe when PUSH-OVER and TIME-HISTORY ANALYSIS are performed.

6-Target displacement of the RC-frame is 105.56mm, when shear-wall is at core while it is 120.15mm when shear wall is at periphery only (in longitudinal direction).

7-Hinges pattern shows that the hinges formed during PUSH-OVER ANALYSIS at the different frame members are not reaching up to the level of IO and remain up to level B (represent yielding).

8-The ductility capacity obtained for shear-core wall building comes out 2.006, while for the frame with shear wall at periphery is 2.363, it shows ductility is more when shear-wall is at periphery. So, the suggested location for shear-wall is at periphery.

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