Stability Analysis of Bottom Double Height Soft-Storey in a Multi-Storyed Satellite Bus-Stop Having Top Soft-Storey and Moment Transfer Beams

Mohammed Mohsin[1] Prof. Vishwanath B Patil[2]
[1]P G Student [2]Associate Professor
[1,2]P D A C E Kalaburagi-585102

Abstract— Popularity of High-Rise structures of rigid frame system are increasing day by day to accommodate growing people in metropolitan city and to construct the structures without any special structural component and Masonry infills are normally considered as non-structural elements and their stiffness contributions are generally ignored in practice. But they affect both the structural and non-structural performance of the RC buildings during earthquakes. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. A similar soft storey effect can also appear at top storey level if a storey used as a service storey. Hence a combination of two structural system components i.e. Rigid frames and RC shear walls leads to a highly efficient system in which shear wall resist the majority of the lateral loads and the frame supports majority of the gravity loads. To study the effect of P-delta, masonry infill and different soft storey level and moment transfer beams, 10 models of R C framed building were analyzed with two types of shear wall when subjected to earthquake loading. Analysis is done by using Etab 2015 software. The results of bare frame and other building models have been compared, it is observed that model with H and L shape shear wall are showing efficient performance and hence reducing the effect of soft storey and also reducing the effect of water pressure in the top soft storey.

Key words: Satellite Bus Stop, stability of building, Soft-Storey, moment transfer beams

I. INTRODUCTION

A. General:

The increase in demand for tall structures requires that a structural engineer is familiar with the buckling phenomena that can occur in a building. The engineer must have an understanding of working calculation methods for designing this type of structure and must having confident in using them. Due to increasing population and land value since from the past few years that bus stands are major problem in populated cities. So construction of Multi Storied buildings with open ground soft storey as used for the movement of Buses (commonly known as Satellite bus stop). These type of building not having masonry infill walls. RC frame building with open ground storey is known as a soft storey, similar soft storey effect can be observed when soft storeys at different levels of structure are constructed. From the past earthquake it has been observed that a building with discontinuity in the stiffness and mass subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building. Most economical way to eliminate the failure of soft storey is by adding shear walls to the tall buildings.

B. Satellite Bus Stop:

Nowadays due to increasing population and the land value since the past few years bus stands in populated cities is a matter of major problem. So that constructions of multi storied buildings with open first storey is a common practice in metropolitan cities (which commonly known as satellite bus stops). Hence the trend has been to utilize the ground storey of the building for the movement of the busses and people can use this as bus terminals. These type of buildings having no infill walls in ground storey, but all upper storeys infilled with masonry walls. Soft storeys at different levels of structure are constructed for other purposes like lobbies conference halls and for the service story's etc. we are considering ground soft storey for movement of busses and top soft storey. Eample of satellite bus stop as shown in fig 1 it is in England in Preston Lancashire.

Fig. 1: Satellite Bus stops

C. Stability:

1) Stability Means:

The resistance offered by a structure to undesirable movement like sliding, collapsing and over turning etc. is called stability.

- Stability depends upon the support conditions and arrangements of members.
- Stability does not depend upon loading

Structural stability can also be defined as "The power to recover equilibrium". It is an essential requirement for all structures.

2) Stable Structure:

A structure is said to be stable if it can resists the applied load without moving or a structure is said to be stable if it has sufficient number of reactions to resists the load without moving.

Unstable structure A structure which has not sufficient number of reactions to resists the load without moving is called unstable structure.

3) Stability of Frames:

A frame is said to be stable if it satisfy the following condition.

– The number of unknown reactions must be greater than or equal to available equations of equilibrium.

Stability is a field of mechanics that studies the behavior of structures under compression. When a structure is subjected to a sufficiently high compressive force or stress, it will have a tendency to lose its stiffness, a noticeably change in geometry, and becomes unstable. When instability occurs, the structure loses its capacity to carry the applied loads and is incapable of maintaining a stable equilibrium configuration.

Buckling is a phenomenon which occurs when a structure is subjected to axial load suffers uncontrolled large displacement, transverse to the load. Transversal buckling, i.e. in plane, has two contributions, bending and shear. The bending deformation causes a curved shape. The shear deformation results in straight inclined shape. Combined they result in the critical buckling mode displayed in Figure 02.

Fig. 2: Combined bending and shear

Examples of structural instability include: buckling of a column under a compressive axial force, lateral torsional buckling (LTB) of a beam under a transverse load, sideways buckling of an unbraced frame under a set of concentric column forces, buckling of a plate under a set of in-plane forces, and buckling of a shell under longitudinal or axial stress, etc.

D. Soft Storey:

The ground storey of a building which consists of open space for parking is known as soft storey. When a sudden change of stiffness takes place along the building height. When the drastic reduction of stiffness is observed is known as soft storey.

A soft story known as weak story is defined as a story in a building that has substantially less resistance or stiffness or inadequate ductility (energy absorption capacity) to resist the earthquake-induced building stresses. Soft story buildings are characterized by having a story which has a lot of open space. Parking garages, for example, are often soft stories, as are large retail spaces or floors with lots of windows. If a building has a floor which is 70% less stiff than the floor above it, it is considered a soft story building (UBC-1997, IBC-2003 and ASCE-2002). Failures of soft storeys can be seen in fig 3(a,b,c,d)

Fig. 3: (a) Ground soft storey failure, Fig 3(b) Intermediate soft storey failure

Fig. 3: (C) Ground Soft Storey Failure Fig 3(D) Soft Storey Failure Pattern

E. Moment Transfer Beams:

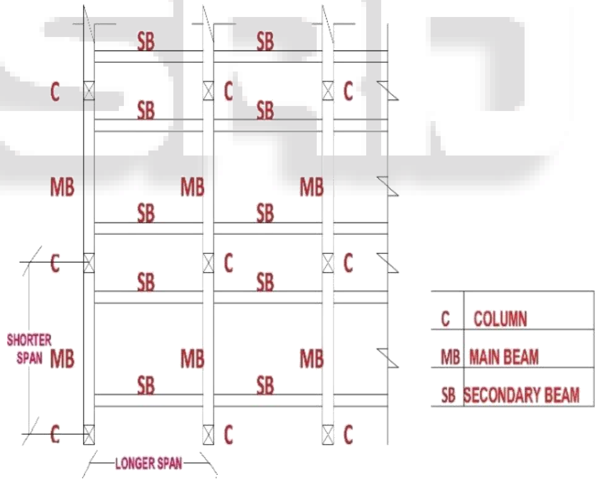

Fig. 4: Normal Plan of Beams And Columns

It is well-understood concept and an inevitable law of statics that loads must be transferred between beams and columns. Main beams are the beams connecting to the columns and secondary beams are the beams supported on the main beams. In the fig Secondary beams are nothing but Moment transfer beams.

Main beams can be of two types:-

– Simply supported or shear connected: The beam-column junction is designed in such a way that no moment is transferred to the columns only the shear force is transferred from the beams to the columns, the moment is carried by beam itself.
– Fixed or moment connection type: The beam-column junction is designed in such a way that moment as well

as shear is transferred to the columns from the beam. All the six degree of freedom of the body is restrained.

In this study we are considering main beams are along shorter span and secondary beams (moment transfer beams) are along longer span. so, this is a satellite bus stop the depth of the beam is very high (due to heavy loads) along both sides, it is not comfortable for double decker buses therefore we are selecting main beams are along shorter span and secondary beams (moment transfer beams) are along longer span for easy movement of busses, Effect of moment transfer beams we are studying and how much floors we can go. Moment transfer beams are considering to transfer bending moments and shear forces.

F. P-Delta:

Any structural model will deflect when it is loaded. A deflected structure may encounter significant secondary moments because the ends of the members have changed position. To illustrate this, consider the simple cantilevered column example shown below

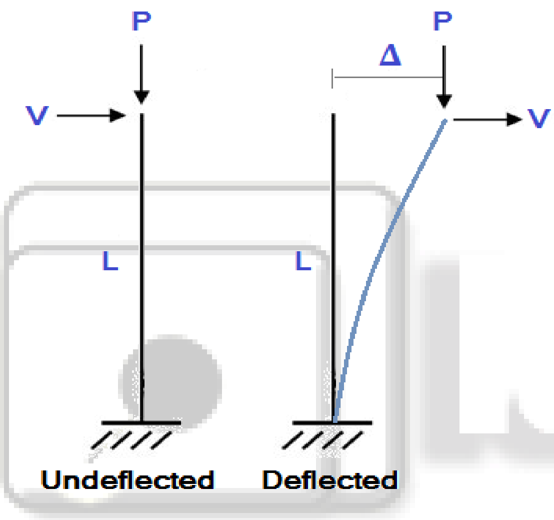

Fig. 5: P-delta effect

In this example, a column of length L is encountering an axial load (P) and a lateral load (V). In a standard linear static analysis. This second-order behavior has been termed the P-Delta effect since the additional overturning moments on the column are equal to the sum of story weights "P" times the lateral displacements "Delta". The P-Delta effect is a destabilizing moment equal to the force of gravity multiplied by the horizontal displacement a structure undergoes when loaded laterally.

P-Delta effects are caused due to geometric non-linearity and for this reason a P-Delta Analysis is often called a Non-Linear Analysis.

.P-Delta effects usually become prevalent in tall structures that are experiencing gravity loads and lateral displacement (due to wind or other forces). If the lateral displacement and/or the vertical axial loads through the structure are significant then a P-Delta Analysis should be performed to account for the non-linearities. In many cases a linear static analysis can severely underestimate displacement among other results compared to a P-Delta (Non-Linear) Analysis.

In some sense, the P-Delta effect is similar to the buckling load.

II. ANALYTICAL MODELLING

Seismic codes give different methods to carry out lateral load analysis, while carrying out this analysis infill walls present in the structure are normally considered as non-structural elements and their presence is usually ignored while analysis and design. Most building codes prescribe the method of analysis based on whether the building is regular or irregular. Almost all the codes suggest the use of static analysis for symmetric and selected class of regular buildings. For buildings with irregular configurations, the codes suggest the use of dynamic analysis procedures such as response spectrum method or time history analysis.

However even though they are considered as non-structural elements, they tend to interact with the frame when the structures are subjected to lateral loads.

In the present study lateral load analysis as per the seismic code for the bare frame, infill frame, ground soft storey, top soft storey with water pressure, both ground and top soft storey, L shaped shear wall, H shaped shear wall, L type and H type shear wall at corner of the plan. Structure is carried out and all the models were analyzed with P-delta and without P-delta effect.

III. DESCRIPTION OF THE BUILDING MODELS

The description of each building model is given below as fallows.

Model 1: Building modeled as bare frame. However, masses of the walls are included considering with P-delta effect.

Model 2: Building modeled as bare frame. However, masses of the walls are included considering without P-delta effect.

Model 3: Building has periphery masonry infill of 230mm thick in all the stories including ground storey and top storey considering with P-delta effect.

Model 4: Building has periphery masonry infill of 230mm thick in all the stories including ground storey and top storey considering without P-delta effect.

Model 5: Building has full masonry infill of 230mm thick in all the stories including ground storey and top storey considering with P-delta effect.

Model 6: Building has full masonry infill of 230mm thick in all the stories including ground storey and top storey considering without P-delta effect.

Model 7: Building model is same as in model 5. Further an addition of L shaped shear wall is provided at corners.

Model 8: Building model is same as in model 6. Further an addition of L shaped shear wall is provided at corners.

Model 9: Building model is same as in model 5. Further an addition of H shaped shear wall is provided at corners.

Model 10: Building model is same as in model 6. Further an addition of H shaped shear wall is provided at corners.

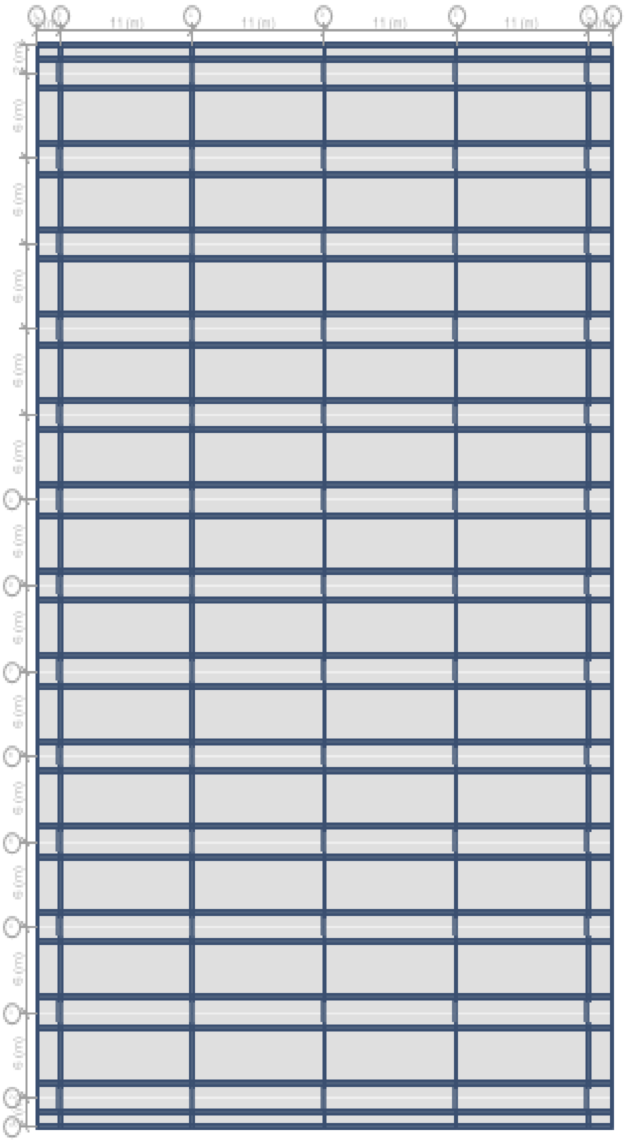

Fig. 6: plan layout

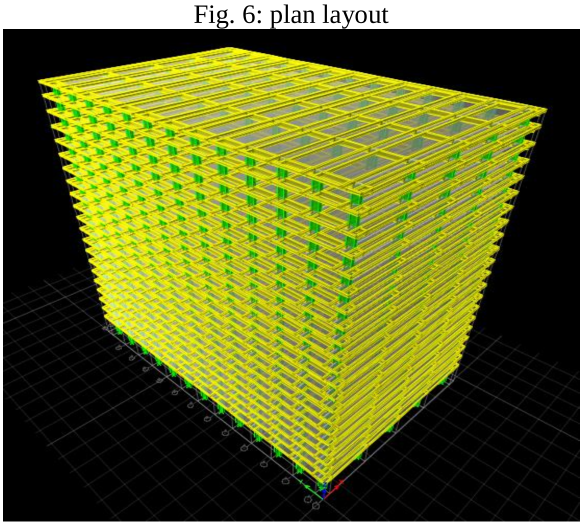

Fig. 7: 3d view of model

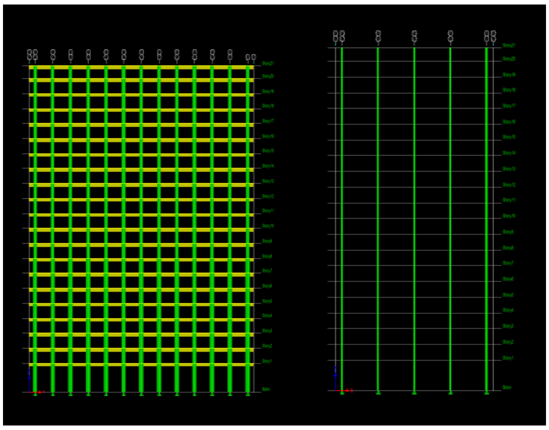

Fig. 8: Elevation in y and x direction

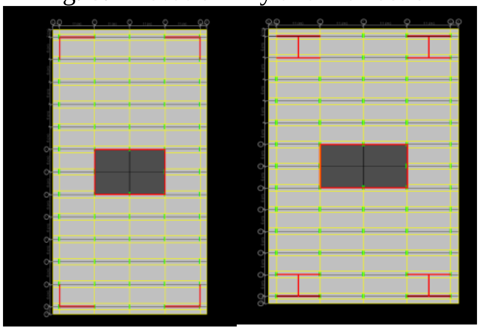

Fig. 9: Plan With L And H Tyoe Shear Wall

A. *Example Building Models Studied:*

The plan layout of the reinforced concrete moment resisting frame building is shown in figure 5.1. The elevation and 3D views of different building models are also shown above. For the study, the plan layout is kept the same for all the models. Each building model is of 21 storeys. The height of each storey is 3.5m except 21^{ST} storey and ground storey, height of 21^{ST} storey is 3.15m and the height of ground storey is kept 7m for all the different building models. The building is considered to be located in seismic zone 2. In seismic weight calculations 50% of floor live load is considered. The input data given for all the different building models is listed below.

Live load	4kn \ m2
Floor finish	1.5 kn \ m2
Slab thickness	125mm
Column	600x1500mm
Beam (along y-dir)	300x900mm
Edge beams	230x450mm
Moment transfer beams	300x450mm

Table 1:

IV. RESULTS AND DISCUSSIONS

A. *Time Periods:*

All objects (including buildings and the ground) have a “natural period,” or the time it takes to swing back and forth. If you pushed the flag pole it would sway at its natural period. As seismic waves move through the ground, the ground also moves at its natural period. This can become a problem if the period of the ground is the same as that of a building on the ground. When a building and the ground sway or vibrate at the same rate, they are said to resonate. When a building and the ground resonate it can mean disaster. One of the most important factors affecting the period is height. A taller building will swing back and forth more slowly (or for a longer period) than a shorter one. Building height can have dramatic effects on a structure's performance in an earthquake. A taller building often suffers more damage than a shorter one because the natural period of the ground tends to match that of buildings taller.

Fundamental time period(Sec)	
MODEL NO.	Time Period
1	14.008
2	11.054
3	4.695
4	3.415
5	3.894
6	2.948
7	0.802
8	0.80
9	0.708
10	0.706

Table 2: Fundamental natural time period using ETABS software

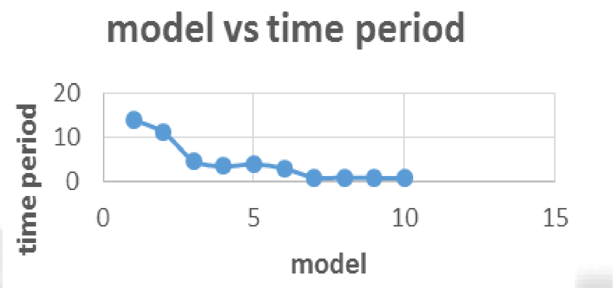

Chart 1: For Time Period

Table 2 shows the time period is obtained by ETABS analysis, Time period for model 2 (bare frame without P-delta) reduces by 21.08% as compared to bare frame model 1(with P-delta). For model 03,05,07 and 09 (with P-delta) reduces the time period 66.48%,72.20%,94.27% and 94.94% when compare with model 01 bare frame model with P-delta. For model 04,06,08 and 10 reduces the time period 69.10%, 73.33% , 92.76% and 93.613% when compare with model 02 bare frame model without P-delta . model 7and 9 when compare with model 8 and 10 time periods are drastic change with 11.72% and 11.75%.

From chart 01 time period by ETABS analysis values are differing for different models. Thus it can be clearly understand that from table 2 and chart 1, presence of brick infill and concrete shear walls considerably reduces the time period of building as shown in chart 6.1 and model with P-delta effect having more time period when compare to without P-delta effect. if stiffness is more , not more change in P-delta and without P-delta effect, can be seen in model 07,08,09 and 10.

B. Storey Drifts:

The permissible storey drift according to IS1893(part1)-2002 is limited to 0.004 times the storey height, so that minimum damage would take place during earthquake and pose less psychological fear in the minds of people. The maximum storey drifts for various building models along longitudinal and transverse direction obtained from Time history analysis (Nonlinear analysis) from ETABS are shown in tables below.

Bare Frame Model (Model 1) Yields Higher Drifts Values As Compared With The Other Models.

Comparison of The Drift Values Of All The Model. From Tha (Nonlinear), From That It Can Be Seen That The Storey Drift In All Storey For Models (With Shear Wall) Has Lower Values As Compare To That For Models (Without Shear Wall). When Masonry Infill Stiffness Taken Into Consideration, Model 5 (Full Brick Infill) Shows Considerable Reduction In Storey Drift. For All Models Drift Is Maximum At Bottom Storey And Slightly Goes Change On Storey 10 (Stiffness Of Column Is Change) And Top Storey (Due To Top Soft Storey). Drift Is Almost Same In With P-Delta And Without P-Delta Effect.

Hence it can be concluded that providing shear wall at corners significantly reduces the drift in the storeys. From the above we can say that if stiffness is more than drift is less.

Storey	Model with P-delta	Model without P-delta
21	0.000596	0.000641
20	0.001564	0.001751
19	0.002468	0.00294
18	0.002484	0.003386
17	0.002171	0.003669
16	0.002136	0.003808
15	0.002569	0.004498
14	0.002949	0.005318
13	0.00302	0.005783
12	0.003066	0.005766
11	0.00346	0.006364
10	0.003768	0.006827
9	0.004019	0.006805
8	0.004327	0.006848
7	0.004603	0.007395
6	0.004858	0.008173
5	0.004935	0.00885
4	0.004621	0.009468
3	0.004156	0.01058
2	0.003635	0.01257
1	0.001952	0.016872

Table 3: Comparison of Storey Drifts between Vs storey

C. Storey Displacements:

The maximum displacement at each storey with respective to ground level are presented in tables obtained from Equivalent static analysis, Response spectrum analysis, Time history analysis for different models. To understand in a better way the displacements for each model along the longitudinal direction and transverse direction are plotted in charts below.

Model 1 and 02 (bare frame) has highest storey displacement values in all different building models, model 01(with P-delta) has more displacement when compare with model 2(without P-delta). Stiffness is added in other stories therefore the displacement is reduced. In X-dir the displacement is more when compare to Y-dir because the stiffness of column is more Y-dir and less in X-dir.

Model 03,05,07 and 09 has less displacement of 97.26%,97.29% , 98.6% and 99.20% when compare with model 01(with P-delta). Model 04,06,08 and 10 has less displacement of 84.71% , 85.20% , 89.163% and 93.55% when compare with model 02 (without P-delta).

Thus it can be concluded that addition of infill and concrete shear wall act as drift and displacement controlled elements in RC buildings. Model with having shear has very less displacement when compare with other models.

Therefore, it can be concluded that as far as tall buildings are concerned, different types of Shear walls and brick masonry infill panel can be a good solution to minimize the effect of soft stories. With consideration of shear walls the effect of P-delta is less.

Storey	Model with P-delta	Model without P-delta
21	7696.372	1004.869
20	7714.136	998.512
19	7741.925	988.784
18	7779.663	975.927
17	7828.535	959.624
16	7888.462	939.733
15	7957.615	916.209
14	8031.442	889.043
13	8101.151	858.213
12	8151.505	823.626
11	8157.879	785.033
10	8082.529	741.864
9	7870.502	692.963
8	7444.632	635.982
7	6875.927	574.879
6	6257.685	511.958
5	5579.205	446.864
4	4831.005	379.264
3	4005.537	308.834
2	3097.871	235.239
1	2106.612	158.133

Table 4: Comparison of Storey Displacements Vs storeys

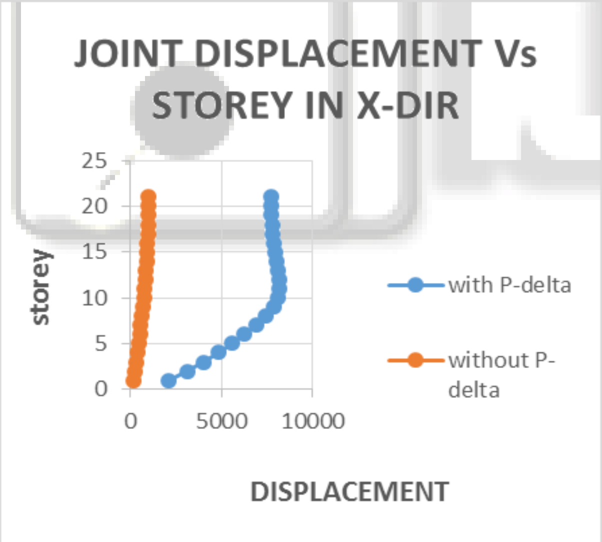

Chart 2: Displacements Vs Storey by Tha

D. Seismic Base Shear:

Storey	Model with P-delta	Model without P-delta
21	1439.851	1332.739
20	3508.853	3242.453
19	4704.236	4381.446
18	4739.69	4728.963
17	3616.744	4645.476
16	2799.368	5198.964
15	3086.07	5840.605
14	3302.934	6624.482
13	3692.036	7293.361
12	3045.699	7004.436
11	3553.799	7081.47
10	3674.001	8112.086
9	3789.772	8629.314
8	3862.2	8776.212
7	3419.883	9070.379
6	3490.524	10422.14
5	3617.071	11409.78
4	3106.539	11520.77
3	2158.055	10923.13
2	3323.733	10728.59
1	5298.332	11754.76

Table 5: Comparison of base shear Vs storeys

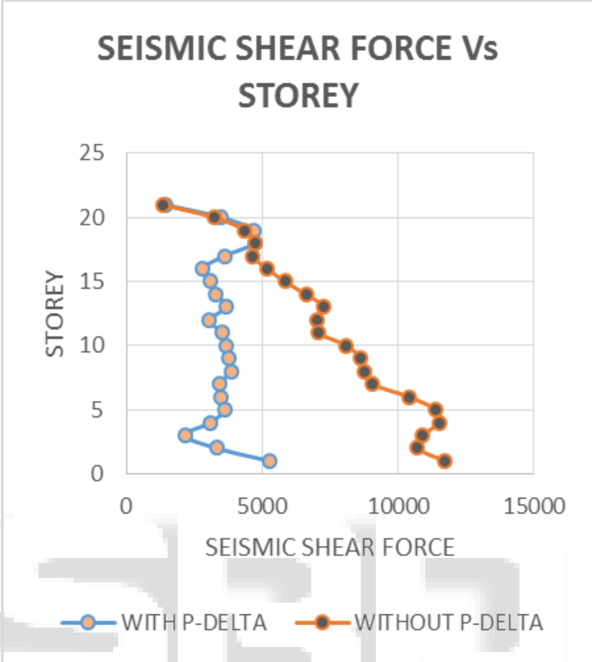

Chart 3: Base Shear Vs Storey by Tha

V. SUMMARY AND CONCLUSIONS

A. Summary:

The present work attempts to study the seismic response RC buildings located in seismic zone-2. In this study all important components of the building that influence the mass, strength, stiffness and deformability of the structure are included in the analytical model. To study the effect of infill wall and different shapes of concrete shear wall in building models. The fundamental time period, seismic base shear, storey displacement and storey drifts are compared by performing Time history analysis. The study leads to the following conclusions.

VI. CONCLUSIONS

1) Bare frame model and model with ground and top service soft storey have got highest dominant time period when compared to different models.
2) P-delta effect having more time period when compare with without P-delta effect.
3) If stiffness is more then the P-delta effect is less when compare with without p-delta effect.
4) H-type shear wall is giving very lesss time period due to more stiffness at corners.
5) Drift is maximum at bottom and top due to soft storeys.
6) If stiffness is more then displacement is less.

7) Models with soft stories have got highest storey drift values at soft stories levels, which leads to dangerous sway mechanism. Therefore providing shear wall is essential so as to avoid soft storey failure.
8) As the number of soft stories increases, the fundamental time period of the structure also increases hence existence of soft stories can make the structure to be flexible in nature.
9) Fundamental time period decreases when the stiffness of masonry infill and concrete shear wall is considered.
10) L type shaped shear wall shows considerably lesser storey drift by THA when considered.
11) Maximum reduction in storey displacement observed by introduction of different types of shear wall.
12) L shaped shear wall shows considerably lesser storey displacement.
13) Providing shear wall at all end corners of the building in X and Y direction significantly improves all parameters in the analysis.
14) Seismic base shear is considerably more for masonry infill and shear wall models as compared with bare frame model.
15) Model with bottom soft storey is very much susceptible to serious damages during lateral seismic loading, because it is observed that hinges are formed in all the columns of ground storey, leading to global damage to the structure.
16) As the contribution of masonry infill and shear wall taken into the consideration the storey drifts and storey displacements considerably reduces, therefore presence of masonry infill and shear wall influence the overall behavior of the structure when subjected to lateral seismic loading.
17) As we add shear wall of l and H shaped at the corners of building in x direction, the effect of soft ground and top soft storey got reduced. Hence shear wall in the form of H and L shape can be good solution to minimize the effect of soft storeys.
18) For tall buildings different type of shear walls and brick infill panel can be a good solution to minimize the effect of soft stories at top and bottom.
19) By providing shear walls at corners the P-delta effect can be ignored.
20) By using moment transfer beams, we can reduce the depth of beam in longer span (carriage way) and can increase the depth of the beam in shorter span (foothpath).
21) By using moment transfer beams we can avoid the floating columns (cumulative loads of floating columns increase the 1st beam size enormously).
22) Seismic base shear is more in p-delta effect and less without p-delta effect.
23) P-delta effect increases BM and forces.
24) P-delta effect increases the joint displacements when compare to without p-delta effect.

VII. Scope for the Future Study

Further study can continue by using various other shapes of shear wall which can be efficient enough in resisting the lateral loads. This study can be further continued by comparing different mode period (along X direction, Y direction and Torsion) for different models.

In this study, symmetrical plan building is considered and future study can be done for unsymmetrical plan buildings. The study carried out by providing fixidity at the base and further study can be done by considering soil-structure interactions. Studies can be carried out by adopting shear wall at different locations in buildings.

Further studies can be conducted on medium to high rise buildings in hilly urban region by providing shear walls at various positions of the building. Studies can be conducted by providing shear wall at the ground storey, which consists of shear wall (or braced frame) and moment resisting frame such that the two systems are designed to resist the total design force in proportion to their lateral stiffness considering the interaction of dual system at all floor levels.

References

[1] Mohammed Khaja Moinuddin and Prof Vishwanath. B. Patil. “Seismic Evaluation of R.C. Framed High Rise Structural System with the Effect of Ground and Intermediate Soft Storey”. International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 8, August – 2014.
[2] Kalappa M Sutar Professor Vishwanath .B. Patil. “Seismic Evaluation of Multi-Storeyed R C Framed Structural System with The Influence of Different Shear Walls and Soft Storeys”. IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 06, 2014.
[3] Misam.A and Mangulkar Madhuri.N. *“structural response of soft story-high rise buildings Under different shear wall location”* Volume 3, Issue 2, July- December (2012), pp. 169-180.
[4] Shahzad Jamil Sardar and Umesh. N. Karadi *“Effect of change in shear wall Location on storey drift of Multistorey building subjected To lateral loads|”.* (IJIRSET)Vol. 2, Issue 9, September 2013.
[5] Stability of Tall Buildings, Daivd Gustafsson & Joseph Hehir Department of Civil and Environmental Engineering Master’s Thesis 2005:12 Division of Structural Engineering Concrete Structures, Chalmers University of Technology Goteborg, Sweden 2005.
[6] Tomislav Igić, Slavko Zdravković, Dragan Zlatkov, Srđan Živković, Nikola Stojić “Stability design of structure with semi-rigid connections” architecture and civil engineering vol 8 nov 02 2010.
[7] Syed Mohammad Zakir Ali M.Tech Student (Structural Engineering) & Amaresha “A Seismic Analysis of RC High Rise Structural Building with Multiple Soft Storey at Various Level using ETabs ”(IJSRD) vol 3, issue 04,2015.
[8] Mohammed Tosif Ahmed Prof Vishwanath. B. Patil. “Influence of Modeling Masonry Infill on Seismic Performance of Multi- Storeyed Building with the Effect of Soft Storeys and Non Dimensional Strength and Stiffness Parameters”. IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 07, 2014.
[9] Amit V. Khandve. *“Seismic Response of RC Frame Buildings with Soft Storeys”.* International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.2100-2108

[10] G V Mulgund et. al. "Seismic Assessment of Masonry Infill R C Framed Building with Soft Ground Floor". International Conference on Sustainable Built Environment (ICSBE-2010) Kandy, 13-14 December 2010

[11] A.S.Kasnale And Dr. S.S.Jamkar. *"Study of Seismic performance for soft basement of RC framed Buildings"*.IOSR Journal of Mechanical & civil (IOSR-JMCE) ISSN: 2278-1684 PP: 47-51 www.iosrjournals.org.

[12] Shaik Kamal Mohammed Azam and Vinod Hosur. *"Seismic Performance Evaluation of Multistoried RC framed buildings with Shear wall".* International Journal of Scientific & Engineering Research Volume 4, Issue 1, January-2013 1 ISSN 2229-5518.

[13] Jaswant N. Arlekar, Sudhir K. Jain And C.V.R. Murty . *"Seismic Response of RC Frame Buildings with Soft First Storeys".* Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, 1997, New Delhi.

[14] Dr. Vinod Hosur. "*Earthquake resistant design of building structures"* Wiley India Pvt Ltd. New Delhi 110002.

[15] O.Esmaili S , Epackachi M , Samadzad and S.R. Mirghaderi. *"Study of Structural RC Shear Wall System in a 56-Story RC Tall Building"* The 14thWorld Conference on Earthquake Engineering October 12-17, 2008, Beijing, China.