Study of Optimistic Location of Soft Story in High Rise RC Building

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Abstract - Now a day's growth of Multi-story building is very high because of rapid urbanization all over the world. Availability of land is minimum due to population, so people end to construct the multi-story building in earthquake prone area also. In soft-story buildings the relative stiffness of the soft-story, typically the bottom story, is significantly less than upper stories due to the presence of large openings which reduce the available space for lateral force resisting system components such as shear walls. Soft story is generally provided for parking, concert hall, Cinema Theater, barn or any purpose in multi-story building, though multi-storeyed buildings with soft storey floor are inherently vulnerable to collapse due to earthquake. This depends on various factors effects on the behavior of multi-story building i.e. irregularity in plan and elevations, uneven distribution of mass etc. To study of different location on the seismic behavior of multi-story building, linear dynamic analysis (Response spectrum analysis) in ETABS software is carried out for Zone IV. In this project an investigation has been made to study the seismic behavior of soft storey building with different arrangement in soft storey building with shear wall and bracings. This analysis is with consideration of strength and stiffness in the upper storey and with and without consideration of braces in the ground storey. Different seismic parameters like time period, story shear, story displacement and story drift are checked out.

Key Words: **Earthquake, Response Spectrum analysis, soft story, shear wall, bracing.**

1. INTRODUCTION

An earthquake is the result of a sudden release of energy in the earth's crust that creates seismic waves. The seismic activity of an area refers to the frequency, type and size of earthquake experienced over a period of time. At the earth's surface, earthquake occurs itself by shaking and sometimes displacement of the ground. When the epicentre of a large earthquake is located offshore, the sea bed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides and occasionally volcanic activities.

An earthquake is measured by seismometers. An earthquake having magnitude of less than 5 are generally measured by Richter magnitude scale & that of magnitude up to 9 or more then 9 is measured by modified Mercalli scale. In its most general sense, the word earthquake is used to describe any seismic event, whether natural or caused by humans that generate seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activities, landslides, blasts and nuclear tests. An earthquake's pint of initial rupture is called its focus or hypocenter. The epicenter is the point at ground level directly above the hypocenter.

Benavent-Climent and S. Mota-Páez (2017) investigated a solution for the seismic upgrade of existing reinforced concrete frames with open first story and masonry infills at the upper stories. It combines the addition of hysteretic dampers with the strengthening (if necessary) of the columns of the first story. The energy-based design procedure put forth provides the strength, stiffness and energy dissipation capacity required for the dampers so that the overall structure can endure the design earthquake without exceeding a prescribed maximum drift at the first story. Non-linear time history analyses conducted on two prototype structures subjected to thirty ground motions showed that the performance of the retrofitted structures is satisfactory, and the proposed procedure provides for a safe-side and not excessively conservative dimensioning of the dampers. The mean-plus standard deviation of the first story drift obtained from the analyses roughly coincides (about 8% lower) with the target drift used for designing the dampers. The probability of having first story drifts larger that the target drift is very low (13%), and in no case the target drift was exceeded by more than 20%. The maximum shear forces in the upper stories predicted with the proposed formulae coincides approximately with the upper bound of the responses obtained from the time history analyses. The residual drift at the first story is less than 0.05% for 83% of the ground motions.

Adrian Fredrick C. Dyaa and Andres Winston C. Oretaaa (2015) have studied the Seismic vulnerability assessment of soft story irregular buildings using pushover analysis .Preliminary seismic risk assessment tools were used to screen existing buildings against potential seismic hazards. Buildings that perform poorly were prioritized for detailed evaluations to determine its condition. The risk of a building can be defined as the product of Hazard, Vulnerability, and Assets. Hazard is the earthquake itself. Vulnerability are building characteristics that make it more susceptible to the hazard. Upon analysis of the modelling results for the soft story building, they have concluded that the main cause for soft story buildings to be more susceptible to earthquakes is the localization of seismic forces. Though the total demand on the building is smaller due to the increased height, uneven demands on the areas of the building results to a local hazard. The forces are concentrated on the segment of the building where there is a reduction in stiffness which is at the location of the soft story. This can be observed through the development of the plastic hinges, the story drift of the buildings, as well as the design. These seismic parameters show a localization of seismic demand.

Varaha Venkata Satya et. al. (2015) purpose of their study is to update the non-linear modeling of soft storey RC frame building for performance based design. The qualitative and quantitative assessment of different strength and ductility parameters of tested building components including the different types of reinforcing steel have been presented. The cyclic performance of tested G+2 soft storey RC frame building of ¼ scale is evaluated and the components test results are applied successfully for performance evaluation of prototype soft storey RC frame buildings under different modes of failure. It indicates that the non-linear characteristics of reinforcement used in different components of building frame have significant influence on the global failure pattern particularly assuring a flexure mode of failure. They concluded that the nonlinear characteristics of reinforcement used in beam components of building frame significantly influence the global failure pattern particularly assuring a flexure mode of failure which is responsible for the ductile response of the structure. It is more pronouncing in case of evaluating the nonlinear performance of bare frames. There is an approximate increase of 50% to 80% ductility as compared to non-specific type of reinforcement by using the high strength and high ductile reinforcement in components of frame buildings.

Rahul Ghosh and Rama Debbarma (2017) attempted to evaluate the seismic performance of setback structures resting on plain ground as well as in the slope of a hill, with soft storey configuration. The analysis has been performed in three individual methods, equivalent static force method, response spectrum method and time history method and extreme responses have been recorded for open ground storeyed setback building. To mitigate this soft storey effect and the extreme responses, three individual mitigation techniques have been adopted and the best solution among these three techniques is presented. They studied the seismic response of setback buildings resting on plain and sloping ground along with soft storey at ground level under earthquake force has been analysed in two different methods, linear static method (ESFM) and linear dynamic method (RSM and THM). Moreover, the extreme vulnerability has been assessed when OGS is considered in these structures. Orthogonal movement under unidirectional force has been recorded for the setback buildings. These structures also reflect differential movement of either sides of the structure, as the taller side moves more than the shorter side along the direction of force. Due to the variation of mass, stiffness and geometry of the setback building, the twisting of the structure also takes place. The columns of the setback buildings at the higher level of the slopes are subjected to higher bending moments; so, special measures should be taken during their design and construction.

1.1 Lateral load resisting systems

Though gravity loads are the primary loading on a building, as a building becomes taller, it must have adequate strength and stiffness to resist lateral loads imposed by wind and earthquake. As the height of building increases, the additional stiffness required to control the deflection, rather than the strength of the members dictates the design. A tall building essentially comprises several vertical cantilevers tied together by the floor slabs. Under horizontal loading, each cantilever bends about its own axis, but deforms in unison with other cantilevers owing to the in-plane rigidity of the floor slabs. The various types of vertical cantilevers used in building are rigid frame, braced frame, wall and tube. They individually or in combination form the structural system which resists the lateral loads in a building. The structural systems used in tall buildings are:

1. Rigid frame
2. Braced frame
3. Shear wall
4. Framed tube
5. Bundled tube

Soft Story Failure: Multi-story buildings in metropolitan cities require open taller first story for parking of vehicle and/or for retail shopping, large space for meeting room or a banking hall owing to lack of horizontal space and high cost. Due to this functional requirement, the first story has lesser strength and stiffness as compared to upper stories, which are stiffened by masonry infill walls. This characteristic of building construction creates weak or soft story problems in multi story buildings. Increased flexibility of first story results in extreme deflections, which in turn, leads to concentration of forces at the second story connections accompanied by large plastic deformation. In addition, most of the energy developed during the earthquake is dissipated by the column of the soft stories. In this process the plastic hinges are formed at the ends of column, which transform the soft stories into a mechanism. In such cases the collapse is unavoidable. Therefore, the soft stories deserve a special consideration in analysis and design. It has been observed from the survey that the damages are due to collapse and buckling of columns especially where parking places are not covered appropriately. On the contrary, the damage is reduced considerably where the parking places are covered adequately. It is recognized that this type of failure results from the combination of several other unfavorable reasons, such as torsion, excessive mass on upper floors, P-Δ effects and lack of ductility in the bottom story. Figure shows some of the examples of soft story. The soft story concept has technical and functional advantages over the conventional construction. First, is the reduction in spectral acceleration and base shear due to increase of natural period of vibration of structure as in a base isolated structure. However, the price of this force reduction is paid in the form of an increase in structural displacement and inter story drift, thus entailing a significant P-Δ effect, which is threat to the stability of the structure. Secondly taller first story is sometimes necessitated for parking of vehicles and /or retail shopping, large space for meeting room or banking hall. Due to this, functional requirement, the first story has lesser stiffness of columns as compared to stiff upper floor rooms, which are generally constructed with masonry infill walls.

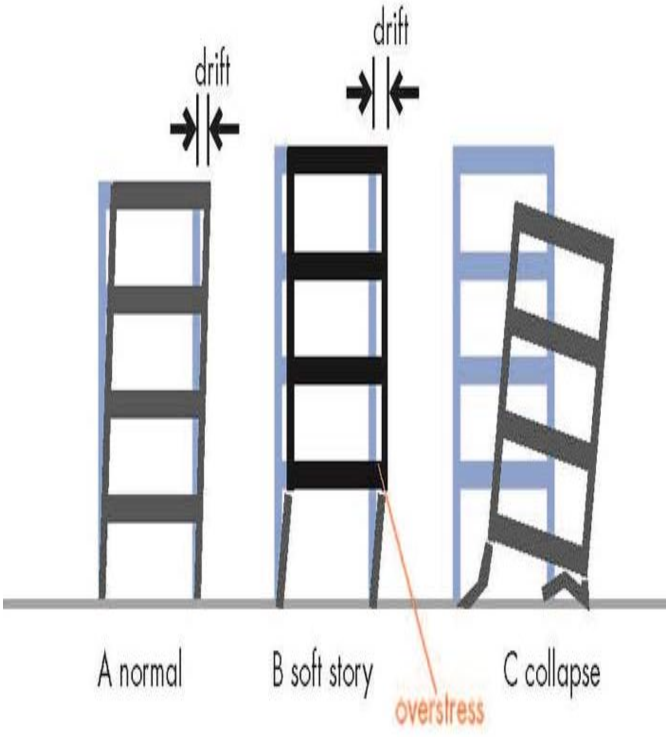
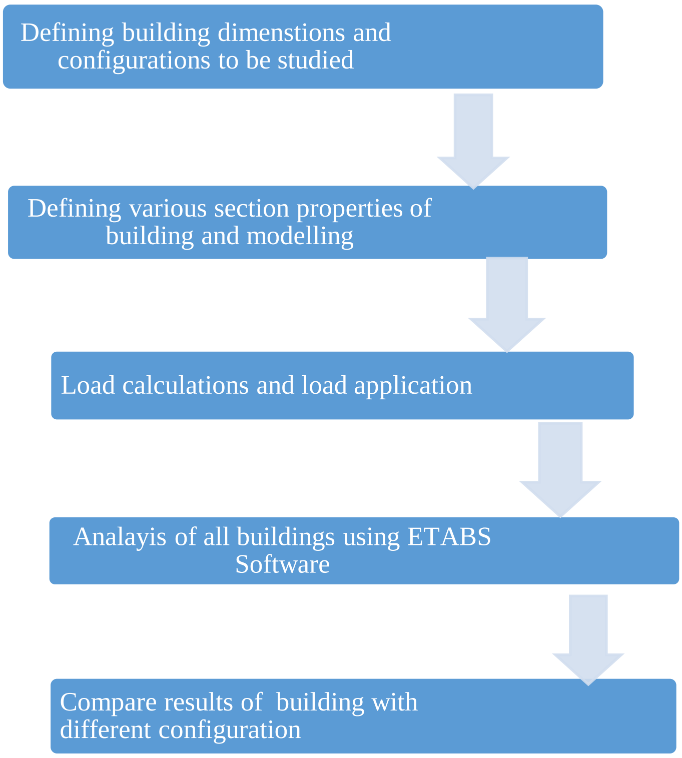


Fig -1: Soft story failure

1.2 Objectives of investigation

1. To analyze a multistoried RC framed building with soft story at different level.
2. To compare base shear results for soft story at different elevations with shear walls and bracing.
3. To compare time period results for soft story at different elevations with shear walls and bracing.
4. To compare maximum story drift results for soft story at different elevations with shear walls and bracing.
5. To compare maximum displacement results for soft story at different elevations with shear walls and bracing.

2. METHODOLOGY



According to objectives defined analysis of RCC building with soft story is carried out using. ETABS software with soft story. Various configuration has been considered as explained. Earlier by using shear walls and bracing systems. Least possible impact of presence of soft story has been evaluated with analysis on the basis of parameters like base shear, time period.

In a present study there are 4 group of building (i.e. configurations) are considered, out of which 1stis without soft story buildings in various zones, 2nd soft story at bottom floor, 3rd soft story at middle floor and 4th soft story at top floor in various zones with shear wall and bracings. The modeling and the analysis of building frames carried out using ETABS software using response spectrum analysis.

In this present study 20 models are studied as described below: -

1. 2 models without soft story in zone IV
2. 6 models with soft story at bottom floor in zone IV
3. 6 models with soft story at middle floor in zone
4. 6 models with soft story at top floor in zone

Table -1: Description of models

Number of story	G+15
Floor Height	4.57m
Slab Thickness	0.125 m
Live load	2 kN/m^2 at each floor
Floor finish Load	1.53 kN/m^2
Concrete grade	M25
Steel grade	Fe500

Table -2: Earthquake parameters

Type of frame	SMRF
Seismic zone (Z)	IV
Response reduction factor (R)	5
Importance Factor (I)	1

Fig -2: Plan of the building in AutoCAD and ETABS (Version 9.6)

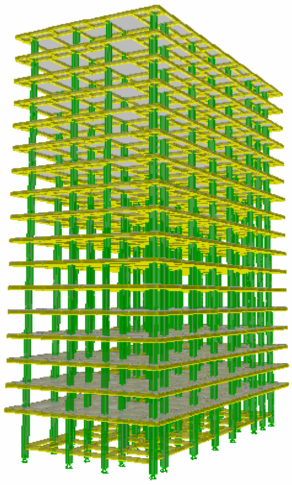


Fig -3: Elevation view of building with soft story at bottom in ETABS

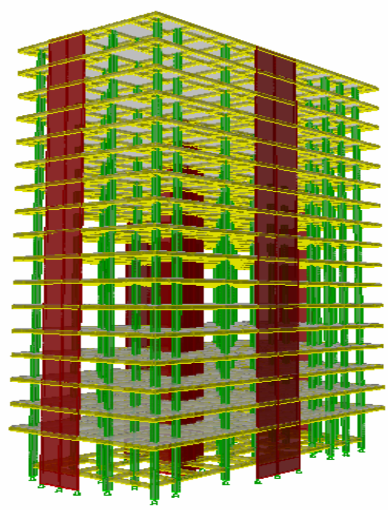


Fig -4: Elevation view of building with soft story at bottom with shear wall in ETABS

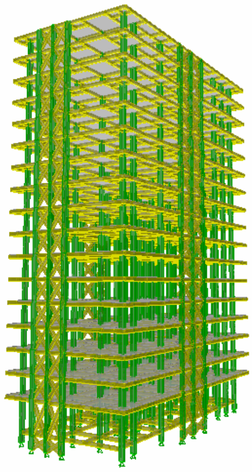


Fig -5: Elevation view of building with soft story at bottom with Bracing in ETABS

3. RESULTS AND DISCUSSIONS

Various parameters are considered for comparisons of different configurations of structure. These parameters serves the basis for evaluating the effect of storey on RCC building and measure to avoid failure by using shear wall and bracing systems.

The base shear for all cases is almost similar due to same seismic weight. Maximum base shear is of 8078 kN with soft storey at bottom case. The time period for soft storey at bottom case is maximum as compared to other configurations. Time period for soft storey with bracing and shear wall is considerably reduced with minimum for soft storey at top with shear wall case. The storey drift for soft storey at middle case is maximum as compared to other configurations. Also storey drift is considerably reduced bY using bracing and shear wall i.e. 50-60 % and 70-80 % respectively for all cases. Maximum storey displacement is highest for soft storey at bottom case. By using bracing displacement is reduced by 45-50 % and by using shear wall it is reduced by 75-80 %. Overturning moment in building is maximum for soft storey at bottom case and is reduced by 5-10 % by using bracing and shear wall in the structure.

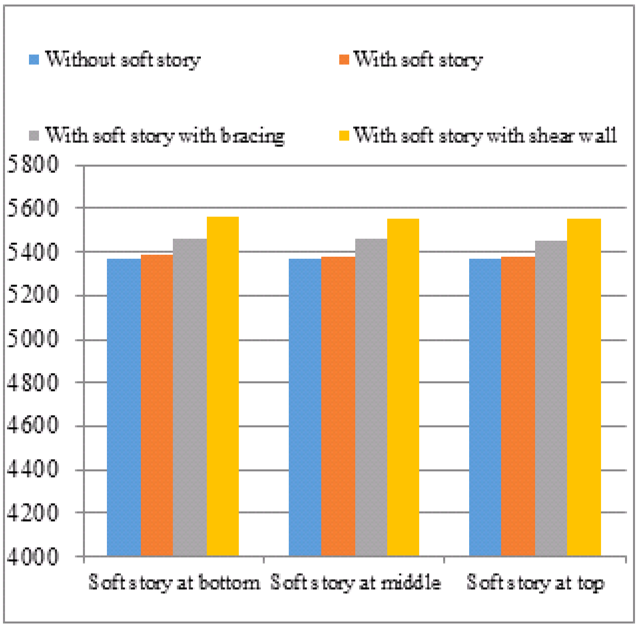


Chart-1: Maximum values of Story Shear in X direction

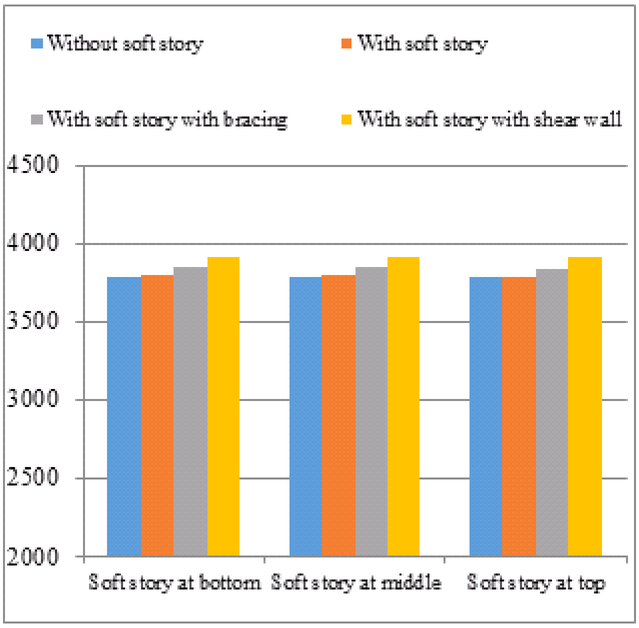


Chart-2: Maximum values of Story Shear in X direction

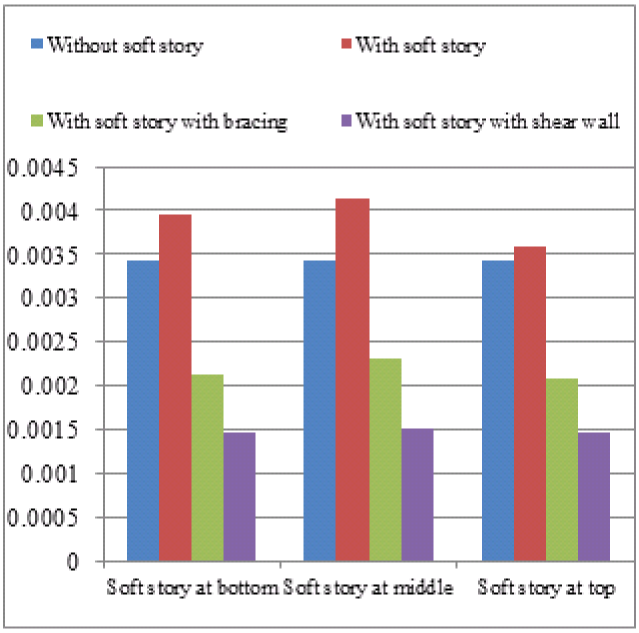


Chart-3: Maximum values of time period

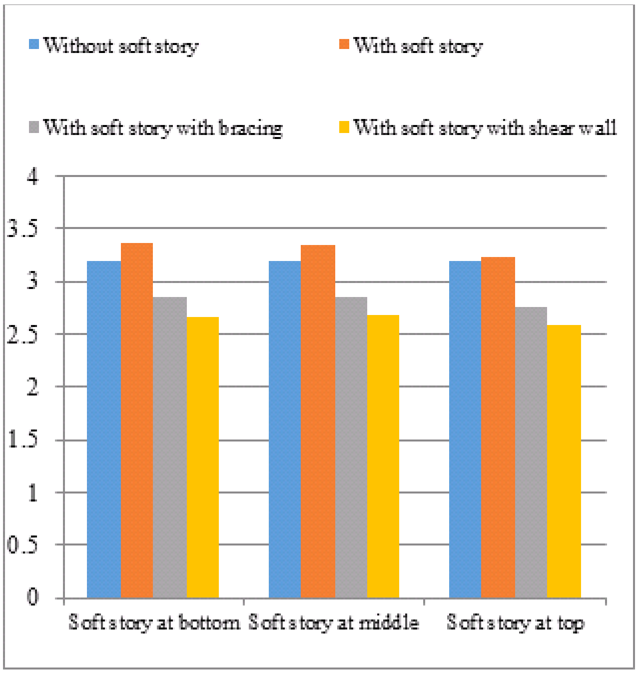


Chart-4: Maximum values of Story Drift in X direction

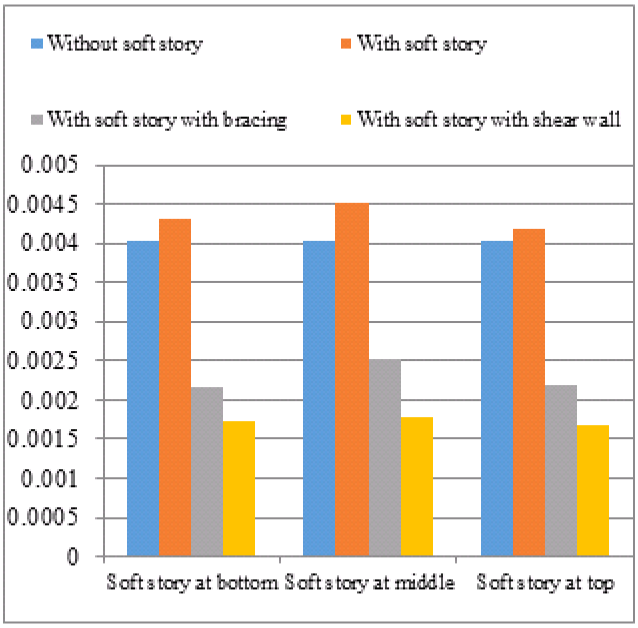


Chart -5: Maximum values of Story Drift in Y direction

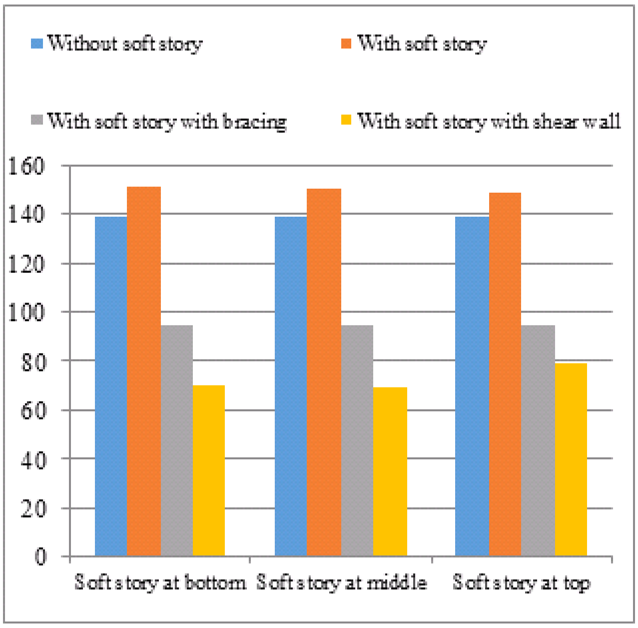


Chart -6: Maximum values of Story displacement in X direction

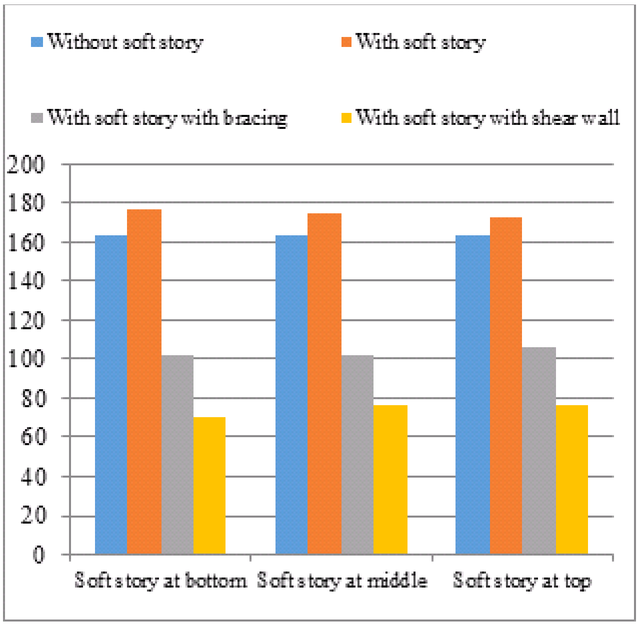


Chart -7: Maximum values of Story displacement in Y direction

4. CONCLUSIONS

From the results obtained, it can be concluded that the time period for soft storey with bracing and soft storey with shear wall is considerably reduced by 15.54 % and 21.9 % respectively with minimum for soft storey at top with shear wall case i.e. 2.593 sec. Storey displacement is maximum for building with soft storey at ground floor case i.e. 265 mm. By using bracing, displacement is reduced by 53.58 % and by using shear walls displacement is reduced by 79.42 %. The storey drift for building with soft storey at 7th floor case is maximum i.e. 0.00453 as compared to other configurations. Also storey drift is considerably reduced by using bracing and shear walls i.e. 56.65 % and 86.2 % respectively for all cases. The base shear for all cases is almost similar due to same seismic weight. There is 1.45 % increment in base shear for soft storey with bracing and 3.17 % increment in base shear with shear wall cases due to increase in seismic weight.

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