A Study on Effect of Soft Storey and Weak Storey in RC Framed Buildings under Different Seismic Zones

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Abstract- *RC structure in the recent time has got a special feature i.e. ground storey is left open for the purpose of social and functional needs like vehicle parking, shops, reception lobbies, a large space for meeting room or a banking hall etc. Such buildings are often called soft storey or open ground storey buildings. During earthquake the major effect to the buildings are due to soft storey and weak storey. Because of less stiffness in soft and weak storey, they cannot withstand the effect of earthquake which results in the collapse of the building. Many studies have shown that there is a sudden collapse of the building if soft or weak storey is present in the ground floor of the building. Increase in the stiffness of the building which have soft or weak storey will reduce the effect of earthquake to the building. Usually they are in ground floor of the building, but they may also be found in other floors of the building. There is a discontinuity in the rigidity of the structure in soft storey level. This is due to lack of infill walls or due to change in floor height. This results in the structural failure of multi-storeyed building during earthquake. Studies have shown the importance of avoiding sudden changes in lateral stiffness and strength. Recent earthquakes show that the reinforced concrete buildings are highly vulnerable and have collapsed during earthquake which had soft or weak storey. The ground floor containing concrete columns behaved like a soft storey. These concrete columns were unable to provide adequate shear resistance during the earthquake.*

Keywords- Soft storey, Weak storey, Seismic Coefficient method, Mode superposition method

I. SOFT STOREY AND WEAK STOREY

Soft storey can be defined as the one in which lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three stories above. The weak storey can be defined as the one in which the storey lateral strength is less than 80 percent of that in the storey above. The storey strength is defined as the total strength of all seismic force resisting elements sharing the storey shear in the considered direction. Many RC framed buildings having soft stories, suffered major structural damage and collapsed in recent earthquakes. The major causes for the damage are large open areas with less infill and exterior walls in ground floor compared to upper floors. In such type of structures, the stiffness of lateral load resisting systems at those stories is quite less when compared to the stories above or below.

Fig 1.1: Columns that are damaged in soft storey during earthquake

1.1 DETAILS OF THE MODELS

Major three models are done. For these models variation of ground floor and introducing equivalent diagonal strut is done. A new concept called double height column is introduced, that is in particular floor slabs, beams (except periphery) and columns (except periphery) are removed. The modeling and analysis was done for zone III and the same building is used for zone II and V. Hence it can be observed that there is huge amount of displacement in bare frame buildings in zone V, The three models are as follows

- Regular building
- Irregular building with symmetry in both directions.
- Irregular building with asymmetry in both directions.

1.2 EQUIVALENT DIAGONAL STRUT

The material and geometrical properties of the equivalent diagonal strut are required to increase the stiffness of the RC frame building with bare frame. The effective width and thickness of the strut are the required geometrical properties. The thickness and thickness of the strut are similar to that of the masonry infill wall of the building.

Many researchers have studied the interaction of the between masonry infill and RC frames. They have reported significant findings regarding the panel’s greater mechanical strength, lower displacement and higher ductility. However, there are wide variety of techniques to evaluate the strength and stiffness of the infill frames.

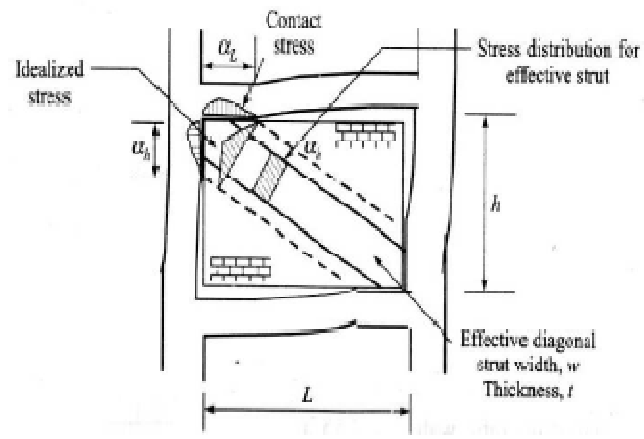


Fig 1.2: Typical equivalent diagonal strut (Drydale, et al, 1994)

II. RESPONSE SPECTRA GENERATION

Ground vibrations during earthquake can cause large amount of damage to the structures leading to loss of human lives and properties. The ground vibrations that occur during earthquake earthquake are influenced by many factors namely

- Mechanism of earthquake that striks at the particular region.
- Properties of the medium through which the seismic waves propogate through.
- Conditions of the region at which the earthquake strikes.

Researchers have shown that the presence of soft soil layers near the earth's surface causes an increase in the amplitude of the seismic waves. This phenomenon is called amplification. It is mainly caused due to the low impedance of soil layers near the earth's surface. The magnitude of the site amplification is dependent on the depth of the bed rock. And also it is dependent on type, thickness and properties of the soil layers above the bedrock. Hence, all these factors have to considered while determining the earthquake ground motions at the given region.

A response spectrum is nothing but a plot of the peak or steady-state response displacement, velocity and acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock. The resulting plot can be used to select the response of any linear system, if we know its natural frequency of oscillations. One such use is finding out the peak response of buildings subjected to earthquake.

If the input used for the calculation of response spectra is steady state periodic, then the steady state result is recorded. Damping should be present, otherwise the response will be infinite. We generally assume some level of damping, but some value will be obtained even without damping.

Response spectra are the curves which are plotted between maximum responses of single degree of freedom system subjected to specified earthquake ground motion and its frequency. It can be interpreted as the locus of maximum response of a single degree of freedom system for given damping ratio. Response spectrum helps in obtaining peak structural responses under linear range. This can be used to obtain lateral forces which are developed in structure due to earthquake thus facilitates in earthquake resistant design of structures.

Usually response of a single degree of freedom system is determined by time domain or frequency domain analysis, and for a given time period of system, maximum response is picked. This process is continued for all range of possible time periods of single degree of freedom systems. Finally, system time period on x-axis and response quantity on y-axis is plotted. This is the required response spectra pertaining to the required damping ratio and input ground motion. To obtain overall response spectra, same process is carried out with different damping ratios.

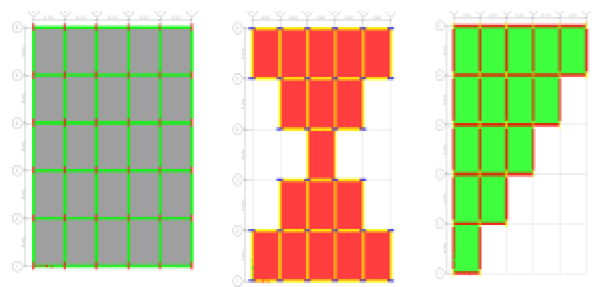
III. SEISMIC COEFFICIENT METHOD

For most of the structures seismic analysis is carried out on the basic assumption that lateral force is equivalent to dynamic loading. Less effort is required for this method because, other than fundamental period, the periods and shapes of higher natural modes of vibration are not required. The total horizontal force on the structure, that is base shear, is calculated on the basis of the mass of the structure, its fundamental period of vibration, and corresponding shapes. The base shear is always distributed along the height of the structure, in the form of lateral forces. This method is usually preferred to low and medium raised buildings.

IV. MODE SUPERPOSITION METHOD

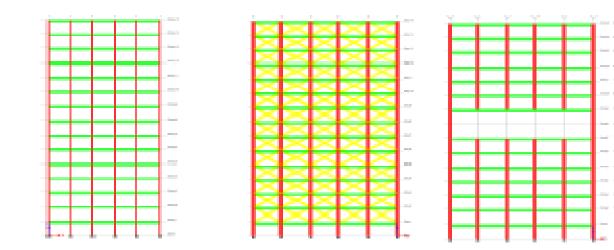
This method is applicable for those types of structures where modes other than fundamental mode is significantly affect the response of the structure. Mode superposition is based on the fact that the certain types of damping, the response in each natural mode of vibration can be computed independently of the others, and the modal responses can be combined to determine the total response. Each mode responds with its own definite pattern of deformation that is mode shape, with its own frequency that is modal frequency and with its own modal damping. For each modal response time history can be computed by analysis of a single degree of freedom oscillator with properties chosen to be representative of the particular mode and the degree to which it is excited by the earthquake motion. The responses are needed to be found only for first few modes because response to earthquake is primarily due to lower modes of vibration.

Generally this method is used for the analysis of dynamic response of the structures, which are not symmetrical or have areas of irregularity or discontinuity. In particular, this method is applicable for the analysis of forces and deformations in multi storey buildings due to medium intensity ground shaking. This causes a moderately large but essentially linear response in the structure. The design Base shears VB` calculated using mode superposition method is compared with the Base shear VB calculated using seismic coefficient method. We can observe that VB is greater than VB`. We should multiply scale factor VB/ VB` for all response quantities, for example member forces, displacements, storey forces, storey shears and base reactions. The value of damping can be taken as 5 percent of critical value, for the purpose of dynamic of RCC buildings.



(a) Regular Building (b) Building with Symmetry in both direction (c) Building with Asymmetries in both both direction

Fig 4.1 Plans of different types of models considered



(a) Bare frame (b) Equivalent Diagonal strut (c) Double height column

Fig 4.2: Elevations of buildings considered for the project work

V. RESULTS AND DISCUSSIONS

Maximum storey displacement and Maximum storey drift are considered as parameters for results and discussions. Graphs are plotted from the result obtained from E – TABS 2015. These graphs are merged according to their Zones are related according to the models prepared.

5.1. TYPES OF COMPARISONS

1 TYPE A: In this type of comparison major parameters considered is Seismic Coefficient method and Mode Superposition Method. In both the methods displacement and drift are considered. Here displacement and drift of all models for all zones are compared. For example regular building with bare frame having varying story height for all zone are compared considering displacement and drift as parameters for both the methods

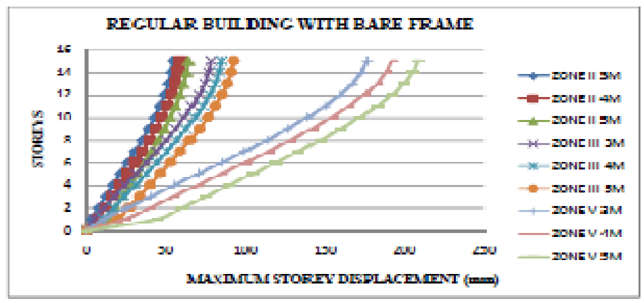


Fig 5.1 Regular building with bare frame (SCM, Displacement)

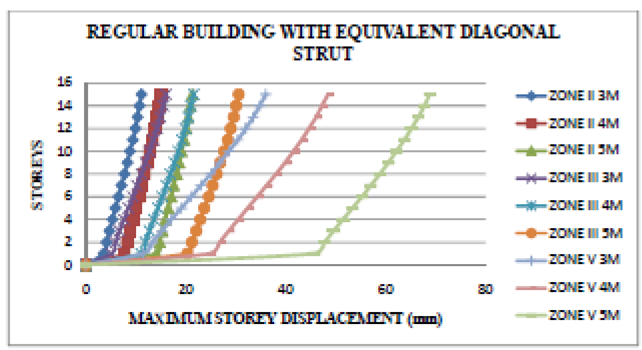


Fig 5.2 Regular building with Equivalent Diagonal strut (MSM, Displacement)

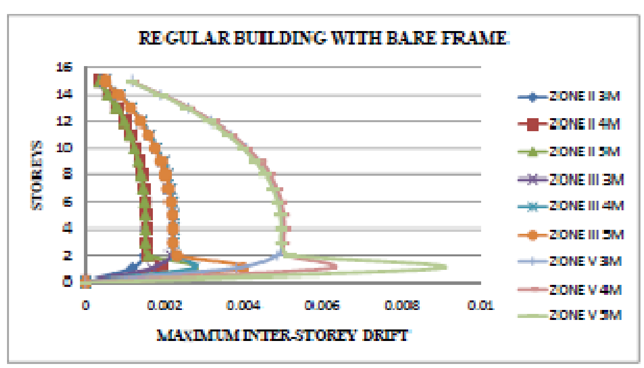


Fig 5.3 Regular building with bare frame (SCM, Drift)

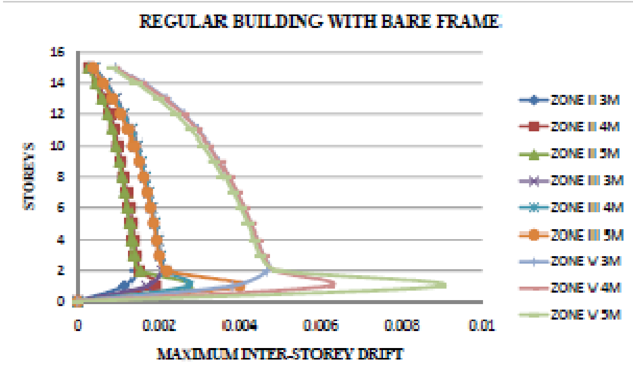


Fig 5.4 Regular building with bare frame (MSM, Drift)

7.2.2 TYPE B: In this type of comparison major parameters considered are Zones which are considered for the project work that is Zone II, III and V. Here also displacement and drift are considered. Two methods that is Seismic coefficient Method and Mode superposition Method are compared for all the models. For example considering Zone II, displacement as a parameter, regular building with bare frame having varying storey height, two methods that is Seismic coefficient Method and Mode superposition Method are compared.

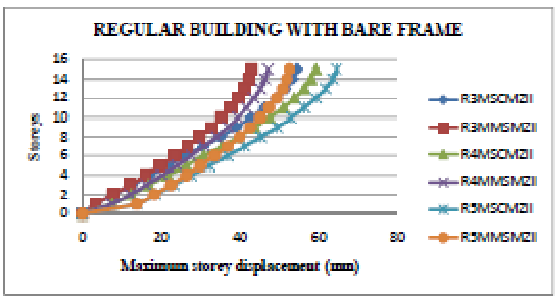


Fig 5.5 Regular building with bare frame by SCM and MSM (Displacement, Z II)

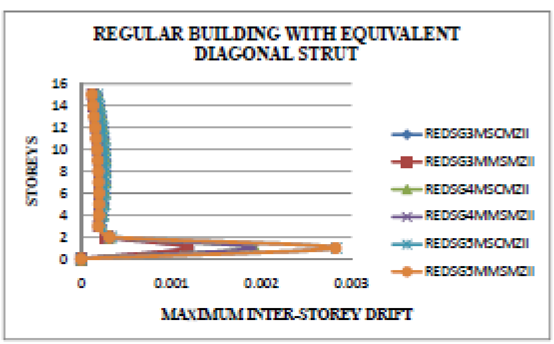


Fig 5.6 Regular building with Equivalent diagonal strut by SCM and MSM (Drift, Z II)

VI. CONCLUSIONS

In regular building with bare frame by Seismic Coefficient method, the displacement is more in 5m storey height building. This is because it has less stiffness when compared to the storeys above. With the increase in height of the ground storey increase in displacement can be observed which clearly shows that there is reduction in stiffness of that storey

In Irregular building symmetric in both directions with bare frame by Seismic Coefficient method, it is observed that for buildings considered irrespective of storey height, there is less amount of displacement observed in all zones considered. This clearly shows that in any zone irregular symmetric buildings will show almost similar displacements irrespective of their storey heights. Same conclusion can be drawn for irregular building asymmetric in both directions

In regular building with Equivalent Diagonal strut by Seismic Coefficient method, it can be observed that there is large amount of reduction in displacement when compared to bare frame building. Here there is an overlapping of 3m and 4m storey height of Zone III on Zone II buildings. This shows that the displacements in these zones are almost similar and behavior of these buildings in both the zones is same. There is a huge amount of increase in stiffness in the buildings because of the provision of Equivalent Diagonal strut. Same conclusion can be drawn for Irregular building asymmetric in both directions.

In Irregular building symmetric in both directions with Equivalent Diagonal strut by Seismic Coefficient method, it can be observed that irrespective of storey heights there is a very close range of graphs for all considered zones and also Zone II and Zone III buildings are very close. This shows that the behavior of these buildings in both the Zones is similar and there stiffness is also almost same.

In Regular building with Double height column by Seismic Coefficient method, it can be observed that buildings provided with strut has less displacement when compared to the one not provided. The stiffness in the strut DHC is more in all zones considered.

In Irregular building symmetric in both directions with Double height column by Seismic Coefficient method, it can be observed that there is an over lapping of strut DHC of zone V with regular DHC in zone II. Though there is difference in the building and zones their behavior is same because the provision of strut increases the stiffness and more over building in zone V is already in severe zone.

The building in zone II with regular DHC has less stiffness. Hence they match up with each other.

In Irregular building asymmetric in both directions with Double height column by Seismic Coefficient method, it can be observed that for storey height 5m there is more amount of displacement in both strut and regular buildings.

In regular building with bare frame by Seismic Coefficient method, it can be observed that there is soft storey effect in 5m storey height building and weak storey effect in 3m storey building. Whereas in case of 4m storey height building there is no such soft or weak storey effect. This shows that is there is similar storey heights in the building then there is a possibility of occurrence of weak storey. If the ground storey height more than 1.5 times the typical storey height then there is soft storey effect. Hence there should be moderate amount of increase in height of ground storey.

In Irregular building symmetric in both directions with bare frame by Seismic Coefficient method, it can be observed that there is soft storey effect in 3m and 4m storey height. 5m storey height building has no soft or weak storey effect.

Here there is no weak storey effect.

In Irregular building asymmetric in both directions with bare frame by Seismic Coefficient method, it can be observed that there is existence of all three cases in this type of building. 3m storey height building has weak storey, 5m storey has soft store and 4m storey height building has no such effects. Hence with moderate ground floor height we can get good results for earthquake resisting building.

In regular building with Equivalent Diagonal strut by Seismic Coefficient method, it can be observed that there are soft storeys in all storey heights of the buildings.

Because of the provision of Equivalent Diagonal strut there is a sudden collapse in the building. 5m storey height building is highly vulnerable to earth quake. Hence ground storey height must be limited.

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