A Comparative Displacement Analysis of Soft Story Structure

[1] Mr. Onkar Sutar , [2] Prof. N. P. Phadatare
[1]Student, [2]Asoociate Professor
[1] Stuctural Enginnering,
[1]PVPIT, Budhgaon, Sangli, India

Abstract : Soft storeys in a multi-storey structure play an important role on its seismic performance. At the soft storey level, there is a discontinuity in the rigidity of the structure due to lack of infill walls. It is this continuity which is the driving force of structural failure of multi storey buildings under seismic loads. In this study, seismic analysis of soft storey building frames have been carried out considering 6 building plans and 4 soft storeys. Soft storeys have been created by neglecting the effect of infill walls. In this way, number of frames are analysed. ETABS software has been used for analysis purpose. Results are collected in terms of max. storey displacements, max. shear force and max. Drift, which are critically analyzed to measure the effects of various parameters.

Key words— **Seismic analysis, Soft Storey, Seismic response, Static analysis.**

I. INTRODUCTION

Soft story is an open storey, which is not much capable of resisting lateral forces especially earthquake loads as compared to non soft storey *floors*. In contemporary times, reinforced-concrete framed structure has a special feature that is the ground storey is left open for the purpose of various needs like parking space, reception lobbies, garage, a large space etc. Such buildings are often called open ground storey buildings or soft storey buildings. Soft storey buildings, having first storey's exhibit much less rigidity than the storey's above are particularly vulnerable to earthquake damage because of large, unreinforced open space on their ground floors. Soft storeys are also been provided in upper floors also to accommodate various needs of building such as gym, restaurants, recreational halls etc. Soft storey buildings are characterized by having a storey which has a large open space. Such a large open space would eventually results is discontinuity in lateral stiffness of structure making it more susceptible to earthquake forces. This paper aims to show how displacement and drift behavior of structure is drastically changes when compared to conventional structures i.e. structure with no soft storey provision.

II. METHODS OF SEISMIC ANALYSIS

For seismic analysis purpose, both linear static analysis and linear dynamic analysis (Response Spectrum Analysis) is performed and results are presented separately.

A. Linear static analysis

Linear static analysis, also known as equivalent static analysis is preferred for moderate height buildings and dynamic analysis is performed for multistorey building. Since, the models analyzed in this work are both of moderate height and of high rise buildings, both linear static analysis and linear dynamic analysis is performed so as to put convenience in studying response. In this method, seismic response of structures is carried out on the principle of horizontal force assumed to be corresponding to the actual earthquake loading.

B. Linear dynamic analysis (Response Spectrum Method)

Response spectrum analysis represents an improvement over linear static analysis. The noteworthy difference between linear static and dynamic analysis is lies in the level of force and their distribution along the height of the structure being analyzed. In response spectrum method, the response of Multi-Degree-of-Freedom system is expressed as the superposition of modal response. Each modal response is then determined from the spectral analysis of Single-Degree-of-Freedom system. Both are then combined to work out total response.

PROBLEM STATEMENT, MODELLING AND ANALYSIS

For the purpose of analysis, following cases of multistorey buildings are considered,

i.   10 storey conventional walled RC structure having plan dimensions 25m × 20m.
ii.   10 storey structure with soft storey in lower storey's having plan dimensions 25m × 20m.
iii.   10 storey structure with soft storey in middle storey's having plan dimensions 25m × 20m
iv.   10 storey structure with soft storey in upper storey's having plan dimensions 25m × 20m
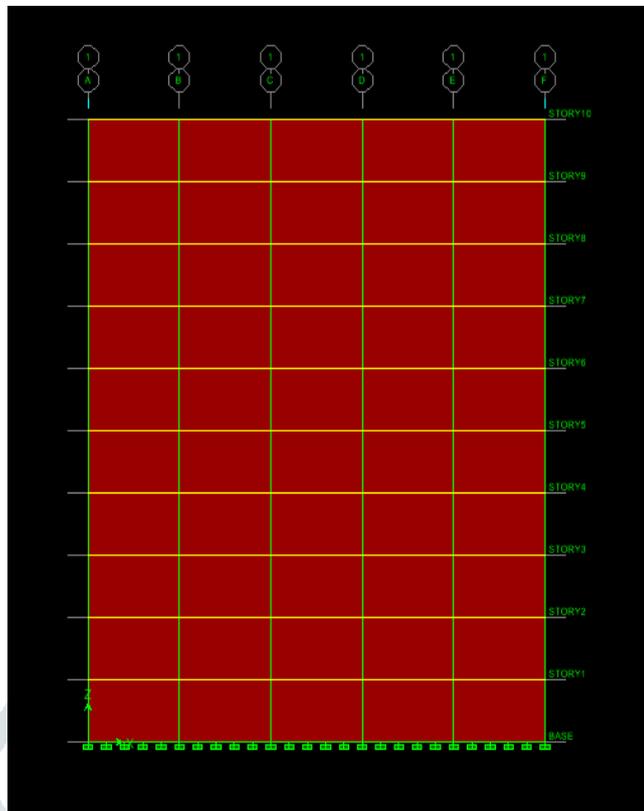
Fig.1

Case 1)- 10 storey conventional walled RC structure having plan dimensions 25m x 20m. In this case, effect of soft storey is neglected and seismic analysis is carried out.
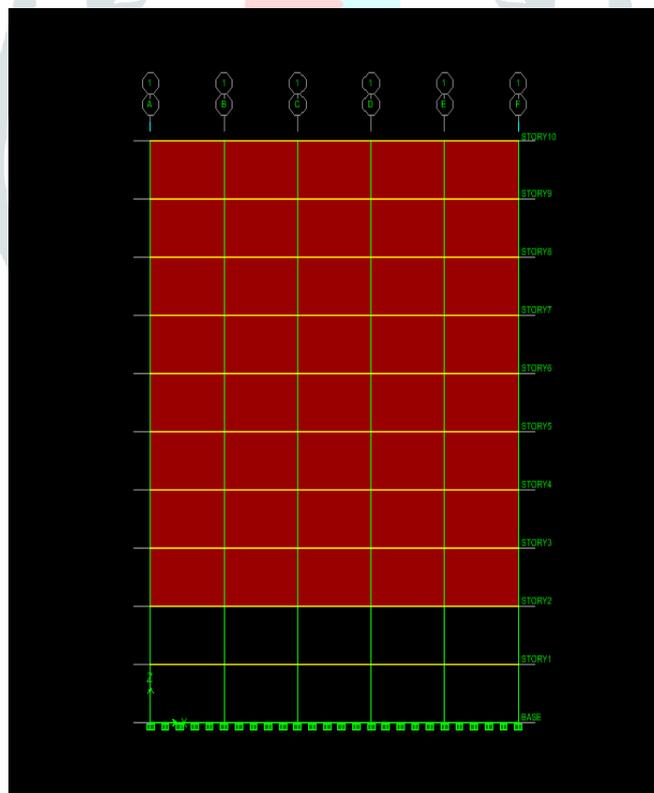

Fig.2

Case 2)- 10 storey structure with soft storey provided in lower part of the structure i.e. for first and second floors only, such cases do exist to accommodate parking space, reception lobby etcetera.
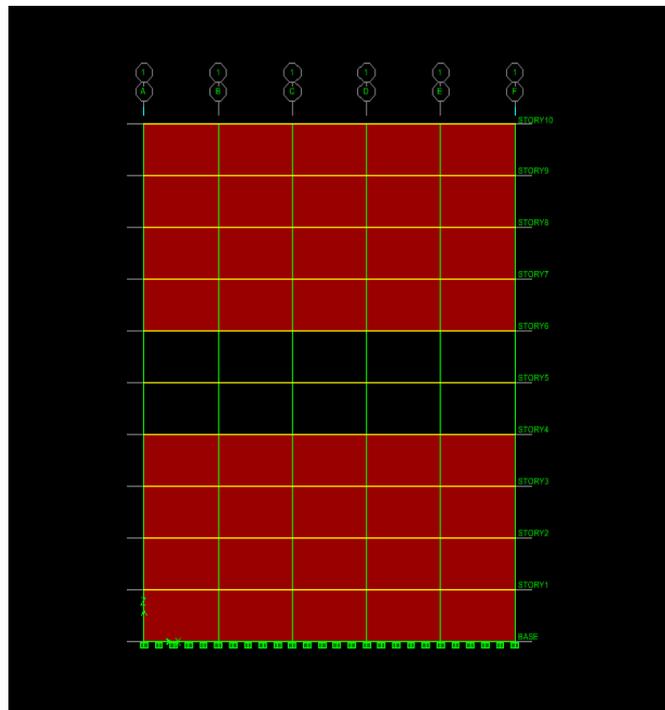
Fig.3

Case 3)- 10 storey structures with soft storey provided in middle part of the structure i.e. for fifth and sixth floors only, such cases do exist to accommodate restaurants, recreational hall etcetera.
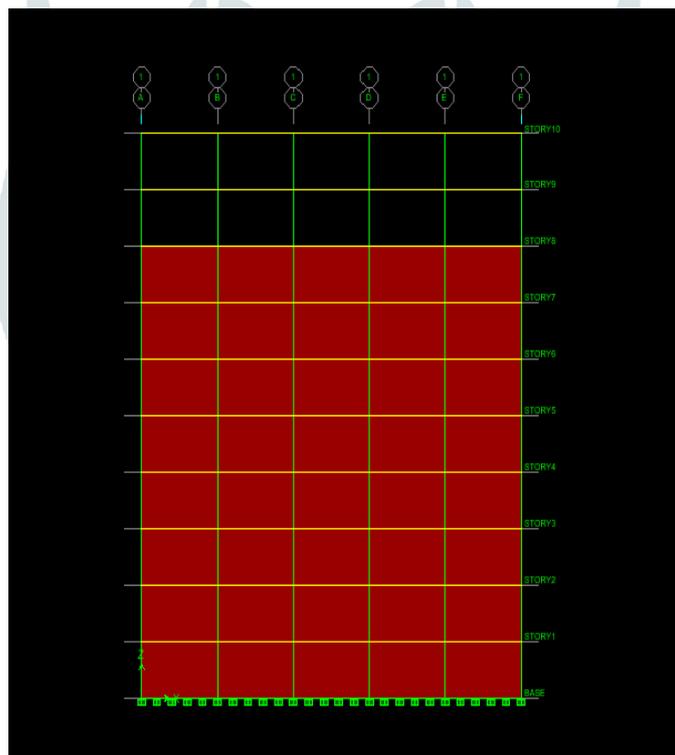

Fig.4

Case 4)- 10 storey structures with soft storey provided in upper part of the structure i.e. for ninth and tenth floors only, such cases do exist to accommodate restaurants, recreational hall etcetera.

Of above four models, first model is analyzed without considering the effect of soft storey, in second case, soft storey is provided in lower part of structure only. In third case, soft storey is provided in middle part of the structure and in last case, soft storey is provided in upper part of the structure i.e. for ninth and tenth floors only. All above cases are analyzed for Linear static analysis method and linear dynamic analysis method.

     a)   Details of Modeling
    i. Typical storey height for all the cases is 3m.
   ii. Thickness of slab is 180 mm and that of drop is 280mm.
  iii. Thickness of wall is 300 mm.
  iv. Size of column varies from 350mm to 1.5m.

Size of beam for conventional structure varies from 300mm to 600mm.

  b) Loading Details

  i. Gravity loads- Gravity load includes dead load and live load imposed on the elements. In addition of the self weight of the elements, the superimposed load for all the floors except top is 1 kN/m^2 and that for top floor is 2kN/m^2. Live load for all the floors except at top is 3kN/m^{2}and that for top floor is 1.5kN/m^2. Superimposed load on all the beams except at top is 12kN/m and that for beams at top floor are 5kN/m.
  ii. Earthquake loading-
   1.   Linear static analysis- The structures are assumed to be located in zone V. The direction of earthquake excitation considered   is X. Program calculated time period is assigned. Importance factor and response reduction factors are 1 and 5 respectively.
   2.   Response spectrum analysis- Square root of sum of squares (SRSS) method is used. Structural and function damping is 0.05.

III. RESULTS

  a) LINEAR STATIC ANALYSIS

Case 1)- Displacement and drift values

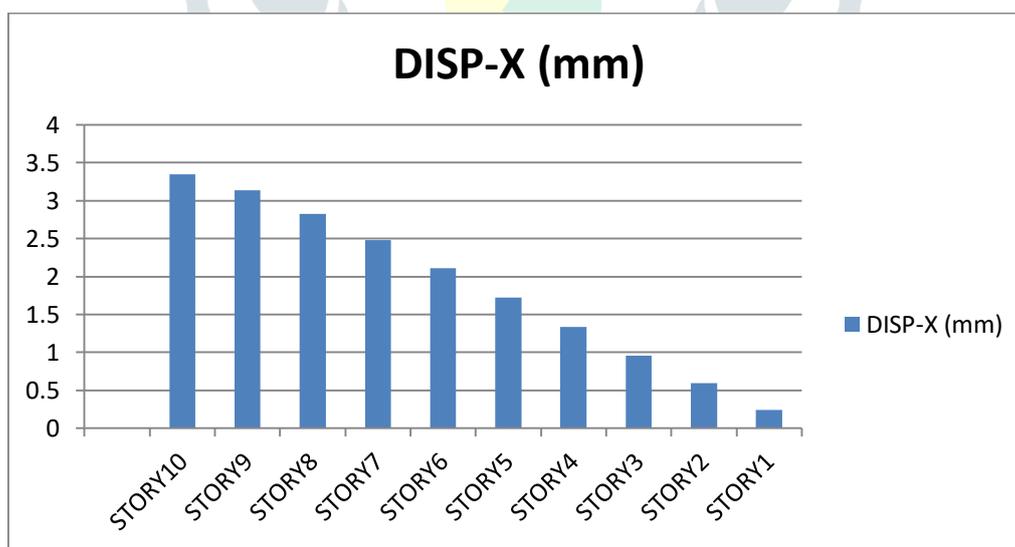| STORY	DISP-X (mm)	DRIFT(mm)
STORY10	3.346622	0.211814
STORY9	3.134808	0.307552
STORY8	2.827256	0.343387
STORY7	2.483869	0.373072
STORY6	2.110797	0.385447
STORY5	1.72535	0.389484
STORY4	1.335866	0.382127
STORY3	0.953739	0.359869
STORY2	0.59387	0.35436
STORY1	0.23951	0.23951

Fig.5- The graph shows the maximum displacement of each storey and of structure as a whole.
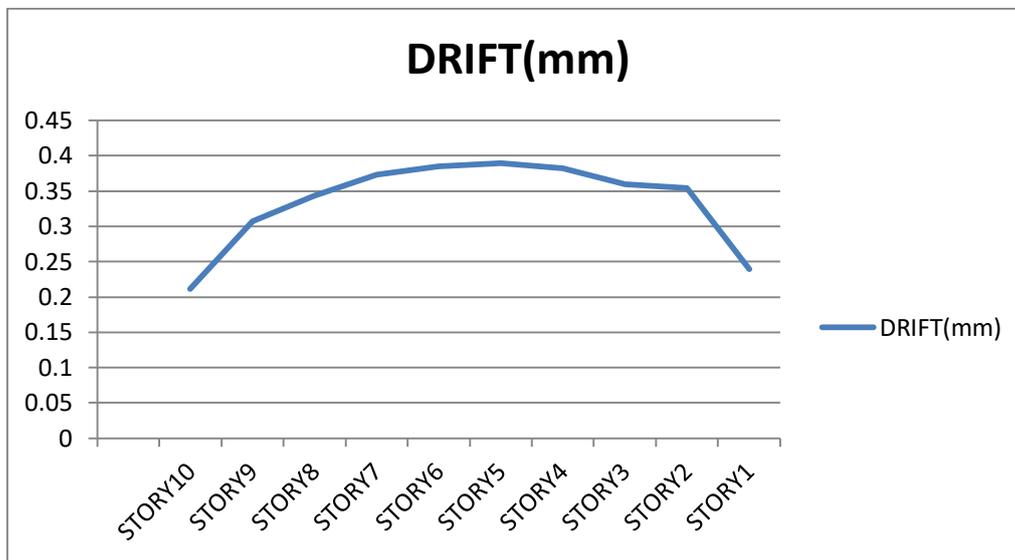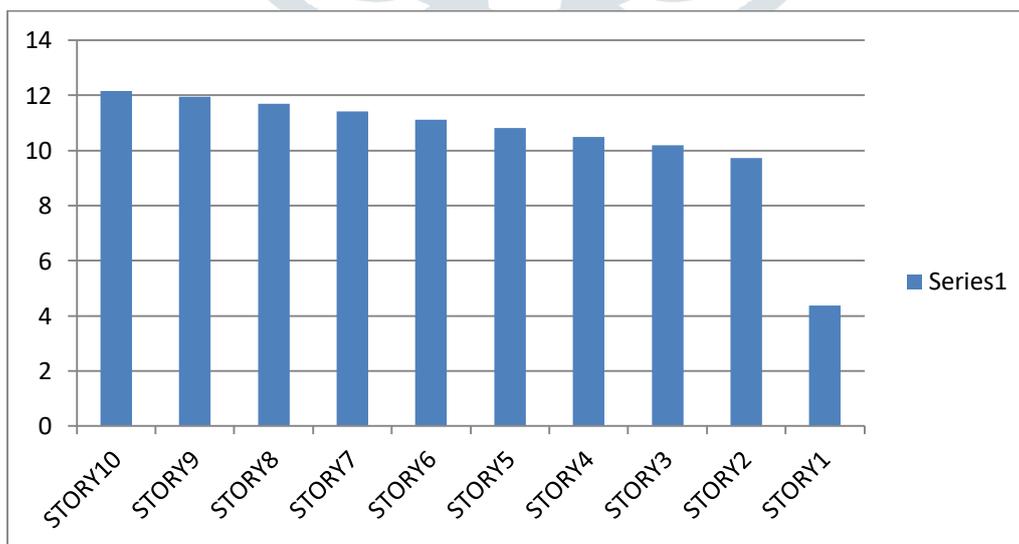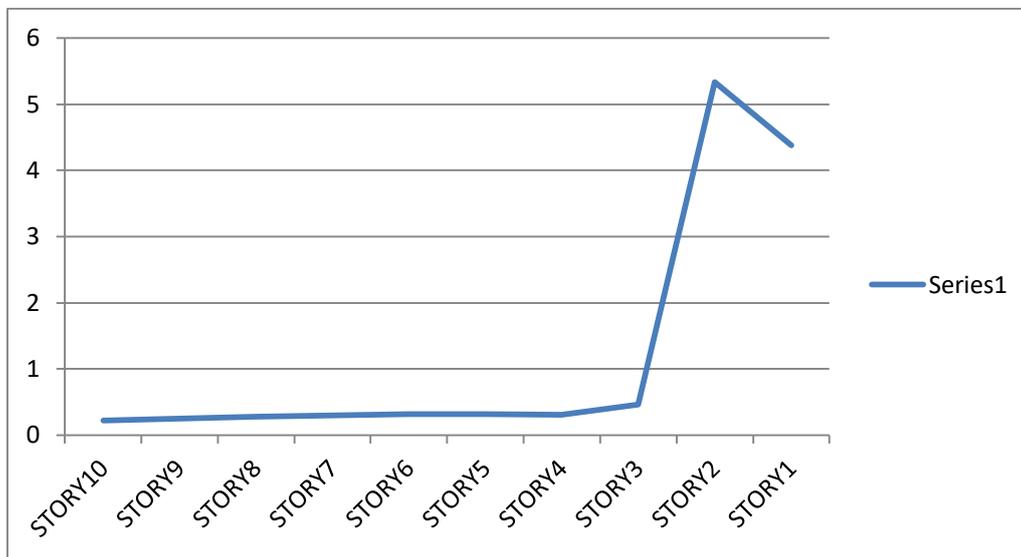
Fig.6- The graph shows the maximum drift of each storey and variation of it along height

Case 2)- Displacement and drift values:

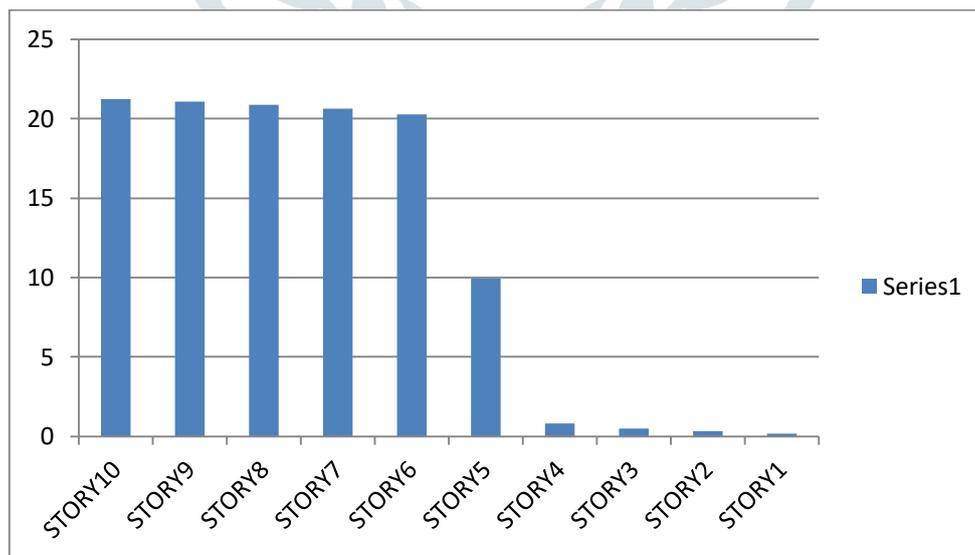| STORY	DISP-X (mm)	DRIFT(mm)
STORY10	12.165868	0.216084
STORY9	11.949784	0.251763
STORY8	11.698021	0.279674
STORY7	11.418347	0.299973
STORY6	11.118374	0.311283
STORY5	10.807091	0.319599
STORY4	10.487492	0.306538
STORY3	10.180954	0.463429
STORY2	9.717525	5.337285
STORY1	4.38024	4.38024

Fig.7- The graph shows the maximum displacement of each storey and of structure as a whole.

Fig.8- The graph shows the maximum drift of each storey and variation of it along height

Case 3)- Displacement and drift values:

STORY	DISP-X (mm)	DRIFT(mm)
STORY10	21.254205	0.17919
STORY9	21.075015	0.215105
STORY8	20.85991	0.228993
STORY7	20.630917	0.360242
STORY6	20.270675	10.319524
STORY5	9.951151	9.153848
STORY4	0.797303	0.318948
STORY3	0.478355	0.167387
STORY2	0.310968	0.168753
STORY1	0.142215	0.142215

Fig.9- The graph shows the maximum displacement of each storey and of structure as a whole.
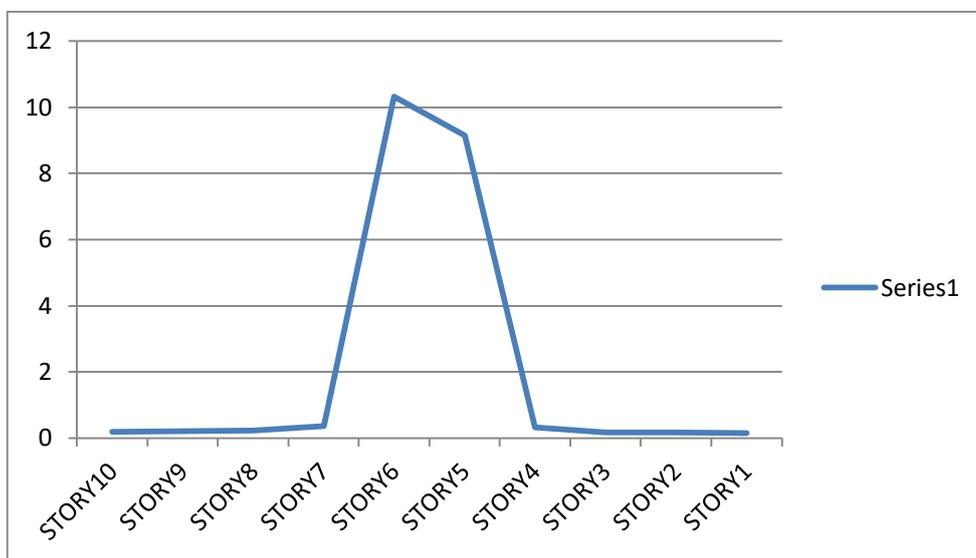
Fig.10- The graph shows the maximum drift of each storey and variation of it along height

Case 4)- Displacement and drift values:

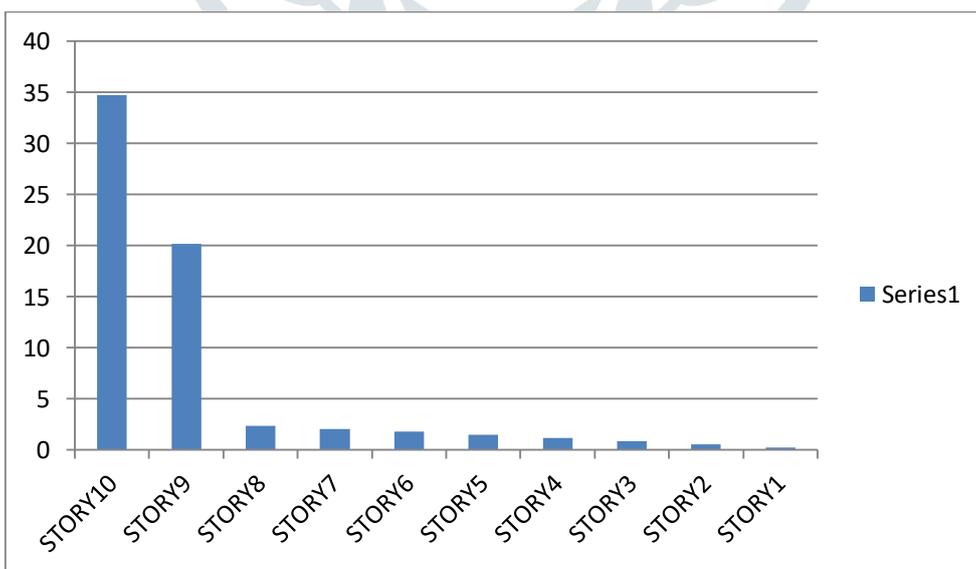| STORY	DISP-X (mm)	DRIFT(mm)
STORY10	34.744986	14.538559
STORY9	20.206427	17.805948
STORY8	2.400479	0.313116
STORY7	2.087363	0.284667
STORY6	1.802696	0.311348
STORY5	1.491348	0.32023
STORY4	1.171118	0.321397
STORY3	0.849721	0.307096
STORY2	0.542625	0.290808
STORY1	0.251817	0.251817

Fig.9- The graph shows the maximum displacement of each storey and of structure as a whole.
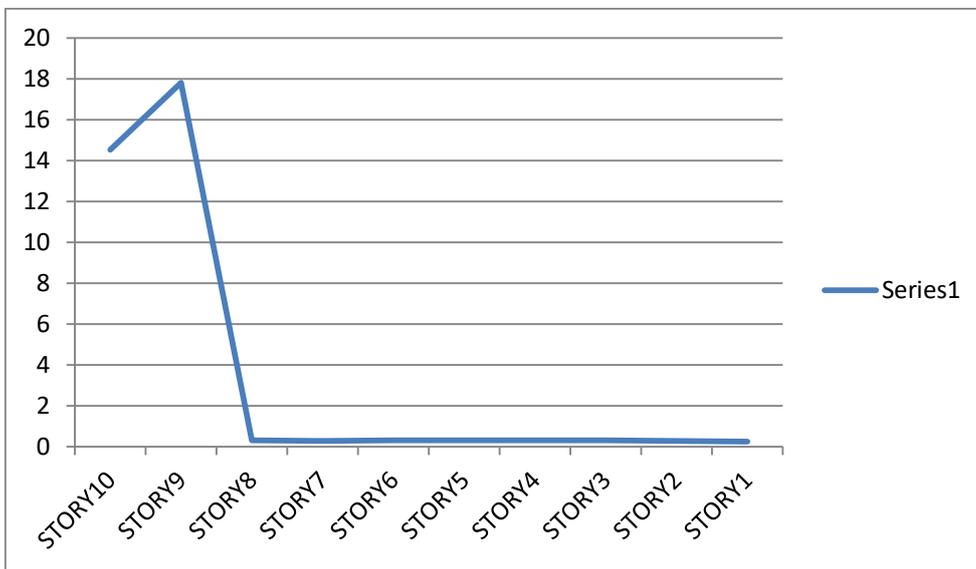
Fig.12- The graph shows the maximum drift of each storey and variation of it along height

b) LINEAR DYNAMIC ANALYSIS

Case 1)- Displacement and drift values

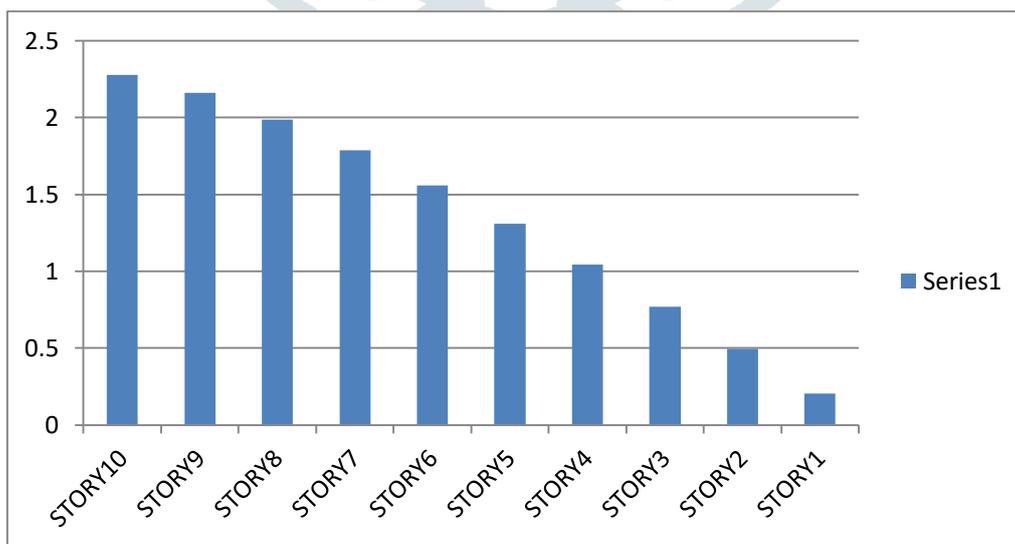| STORY	DISP-X(mm)	DRIFT(mm)
STORY10	2.276385	0.115545
STORY9	2.16084	0.172184
STORY8	1.988656	0.200741
STORY7	1.787915	0.228594
STORY6	1.559321	0.248766
STORY5	1.310555	0.265312
STORY4	1.045243	0.275314
STORY3	0.769929	0.276128
STORY2	0.493801	0.290008
STORY1	0.203793	0.203793

Fig.13- The graph shows the maximum displacement of each storey and of structure as a whole.
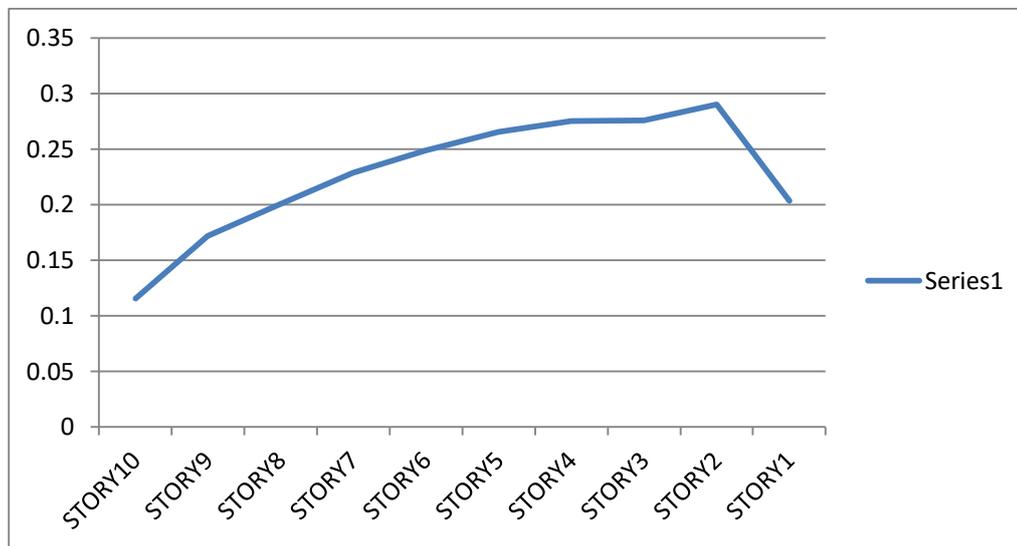
Fig.14- The graph shows the maximum drift of each storey and variation of it along height

Case 2)- Displacement and drift values:

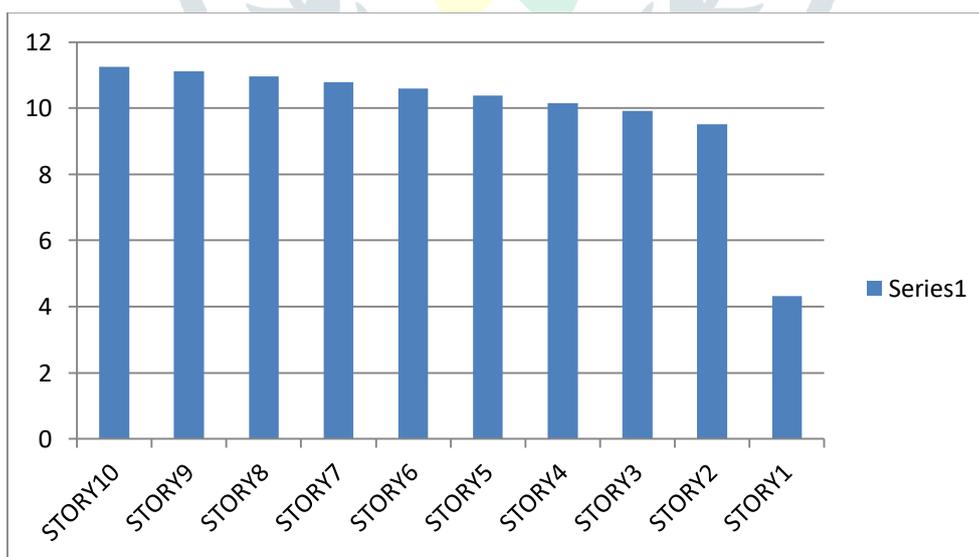| STORY	DISP-X (mm)	DRIFT(mm)
STORY10	11.260421	0.139349
STORY9	11.121072	0.158965
STORY8	10.962107	0.177869
STORY7	10.784238	0.196225
STORY6	10.588013	0.212596
STORY5	10.375417	0.231494
STORY4	10.143923	0.233854
STORY3	9.910069	0.404996
STORY2	9.505073	5.191801
STORY1	4.313272	4.313272

Fig.15- The graph shows the maximum displacement of each storey and of structure as a whole.
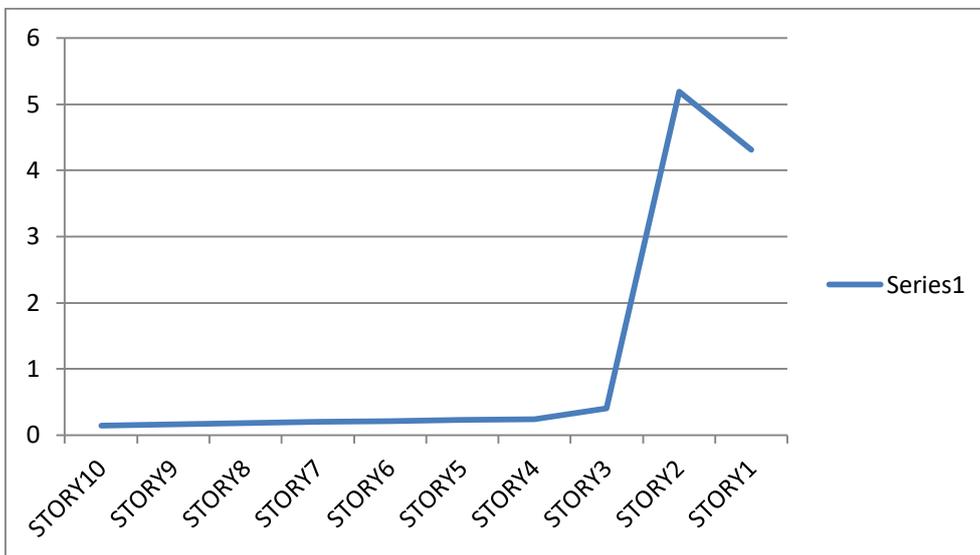
Fig.16- The graph shows the maximum drift of each storey and variation of it along height

Case 3)- Displacement and drift values:

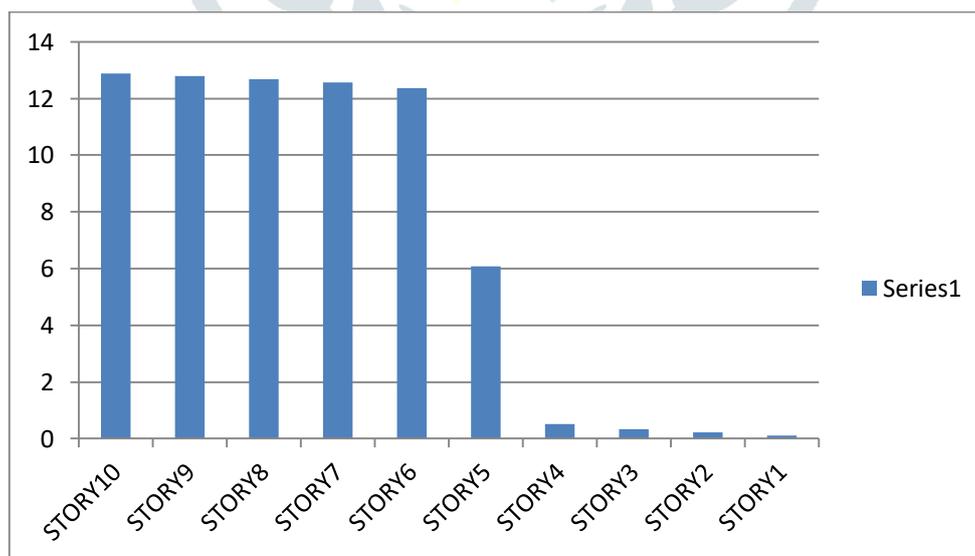| STORY	DISP-X (mm)	DRIFT(mm)
STORY10	12.881704	0.091823
STORY9	12.789881	0.110227
STORY8	12.679654	0.119098
STORY7	12.560556	0.202955
STORY6	12.357601	6.272556
STORY5	6.085045	5.575312
STORY4	0.509733	0.185205
STORY3	0.324528	0.107277
STORY2	0.217251	0.115346
STORY1	0.101905	0.101905

Fig.17- The graph shows the maximum displacement of each storey and of structure as a whole.
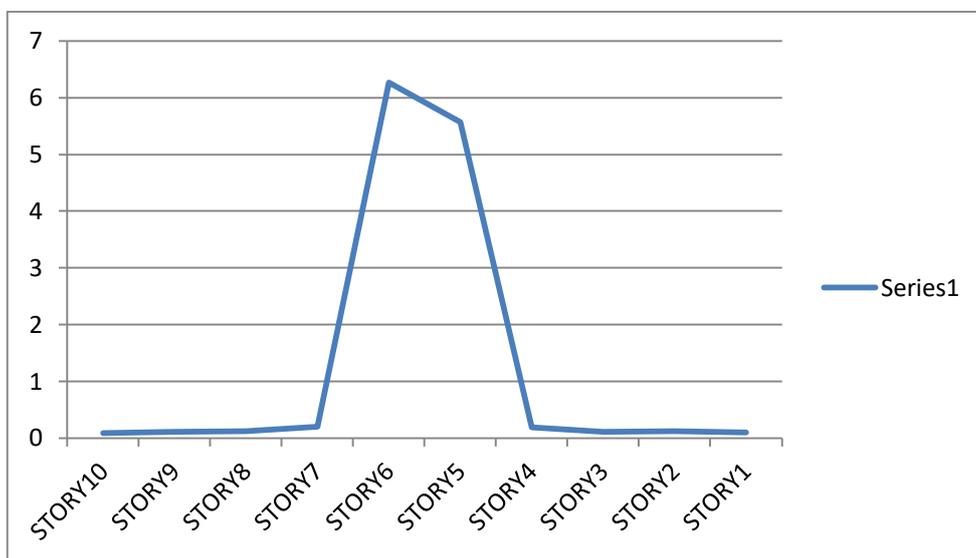
Fig.18- The graph shows the maximum drift of each storey and variation of it along height

Case 4)- Displacement and drift values:

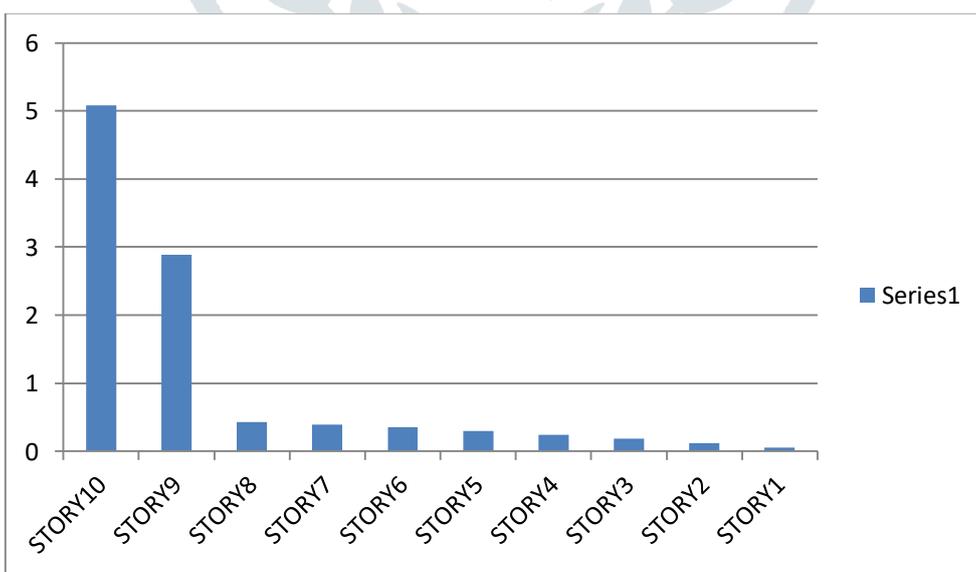| STORY	DISP-X (mm)	DRIFT(mm)
STORY10	5.08101	2.189668
STORY9	2.891342	2.462411
STORY8	0.428931	0.035876
STORY7	0.393055	0.041043
STORY6	0.352012	0.049476
STORY5	0.302536	0.056045
STORY4	0.246491	0.061271
STORY3	0.18522	0.063387
STORY2	0.121833	0.06428
STORY1	0.057553	0.057553

Fig.19- The graph shows the maximum displacement of each storey and of structure as a whole.
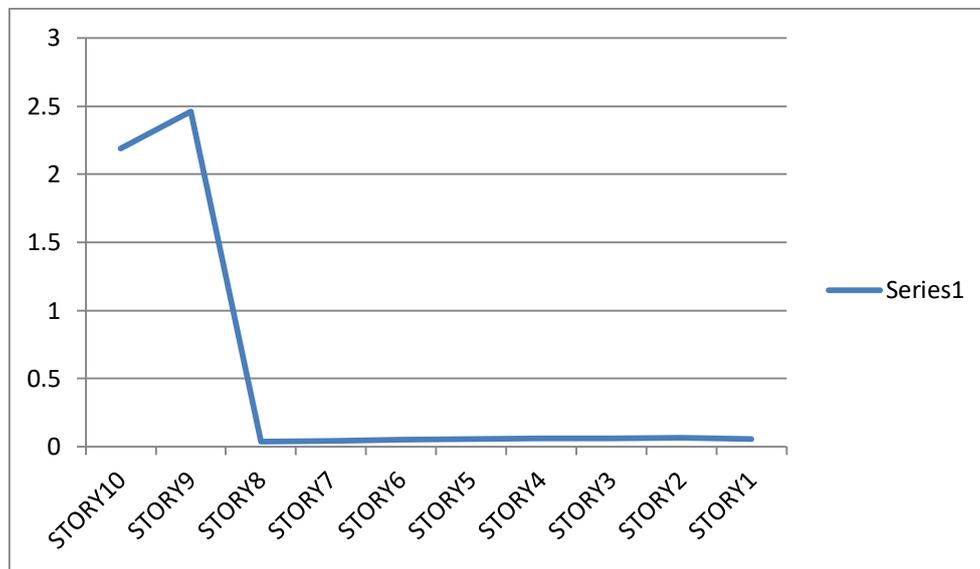
Fig.20- The graph shows the maximum drift of each storey and variation of it along height

Storey drift-

     Storey drift is the total lateral displacement that met in a single storey of a high-rise building. It is one of the predominantly important engineering response quantity and indictor of structural performance, in particular for multi-storey buildings. Storey drift is considered as unique standard for structural behavior conclusion.

     IS 1893 (Part 1): 2002 laid out standards for maximum allowable storey drift as "*shall not exceed 0.004 times the storey height under consideration."* For all the cases analyzed in this work, storey height considered is 3m. Therefore, maximum allowable storey drift in this case is 12mm.

     The analytical results shows that flat slab structures does not exceed maximum allowable storey drift for moderate height structure, but with increase in height necessitates the provision of lateral load resisting element as storey drift is likely to exceed the allowable limit. In this case, storey drift exceeds for with 20 storeys.

IV. CONCLUSION

1. For all case, the displacement of the structure varies linearly i.e. displacement values increases as there is increase in story height
2. Storey drift follows a parabolic path with higher value somewhere at the middle to leaning towards upper storey.
3. Storey drift for soft storey structures in lower portion of structure is within allowable limit and not exceeding the permissible limit..
4. Storey drift for soft storey structures in middle portion of structure is almost on the verge of exceeding limiting values but still not exceeding the permissible limit..
5. Storey drift for soft storey structures in upper portion of structure is exceeding permissible limit making it much susceptible to earthquake forces in comparison with other structures.

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