INFLUENCE OF STIFFNESS DISCONTINUOUS DIAPHRAGM CHARACTERISTICS ON THE SEISMIC BEHAVIOR OF RC STRUCTURE

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***ABSTRACT*-Researchers of past and present earthquake had caused more damage to the R.C structural buildings that fairly exposed to the damage and sudden breakdown of RC buildings during lower and strong ground motion. Diaphragm act as roof and roof system in concrete based reinforced building under seismic loading, these diaphragm transfers the series of lateral loads to the vertical members. In this present study, an attempt is made study the influence of various parameters associated with diaphragm on the seismic behavior of RC framed structure. Attempts are made to study the effect of discontinuities in the diaphragm namely 0%, 10%, 20%, and 30% openings with comparing the seismic behavior of four and eight story RC building. For this purpose, ETABS 2015, FE analysis software withResponse Spectrum Analysis as per IS 1893 is used to assess the seismic behavior.Parameters such as Natural Time Period, Base Shear, Mode shape, Drift and Displacements and internal forces in members are used to compare the seismic performance.**

Key Words: stiffness diaphragm, Dynamic Analysis, ETABS 2015

I. INTRODUCTION

Diaphragm act as roof and roof system in concrete based reinforced building under seismic loading, diaphragm transfers the series of lateral loads to the vertical members and where as Floors play an important role in distributing seismic forces to vertical sub-structure; in the mass centers at each rigid floor have three degree of freedom represents two in plane translation and one in plane rotation. These plane translation and plane rotations are called as slaved nodes. The main function of the diaphragm is to transfer the torsion and shear from lateral members and distributing it to vertical resisting members. Stiffness diaphragm determines how stiffness diaphragm transfers torsional moment and shear from lateral member to vertical member. In frequent cases revealed that structural weakness tends to form discontinuities in mass, stiffness and strength along the sides of diaphragm. These discontinuities in the diaphragm are equal to the sudden change in geometry along the length of building. According to IS 1893:2000 building with discontinuities gives lesser deformation and it is more used in earthquake affected areas.

Scope and Objectives of the Study

- To study the discontinuities of diaphragm by seismic analysis in the RC building.
- To compare the behavior of different discontinuities in the diaphragm systems during earthquake loading.
- To study the above objective using response spectrum analysis with the help of using ETABS 2015 software considering the parameters such as natural time period, drift, displacement and base shear.

II. Methodology

- To succeed the above objectives from the following step-by-step procedures

- A thorough literature review to understand the seismic evaluation of building structures and application of Response spectrum analysis
- Selecting a four and eight story RC building with 0%, 10%, 20%, and 30%diaphragm discontinuity and will be analyzed as per Indian Standard for dead load, live load, and earthquake load.
- In analysis, design of three-dimensional structures in seismic loadings, the diaphragms often assumed to be perfectly rigid
- Analyze the building using seismic analysis method such as Response spectrum in ETABS 2015.
- Analyzedresults will arrive in conclusions.

ABOUT ETABS 2015 SOFTWARE
INTRODUCTION

ETABS 2015 abbreviated as extended three dimensional analysis building system program. A very useful software program matured by computers and structure and that is improved by engineer's analysis and design ability for any civil structure. This software powers stay in array of option and features the other part how easy to use it. User creates a model using grid lines, structural property, object tools and in last detailing about the material. Dynamic property such as mass source, mode shape and direction of modes can be specified and analysis can be performed based on graphical, numerical and in tabular form too. The following steps define some important concept in analyzing using ETABS 2015

ANALYSIS OF GRAVITY AND LATERAL LOADS IN ETAB 2015

The model is started with grid lines and depending upon size of the structure. Defining each component of the structure such as material, diaphragm etc. for further we apply the loads andapplying the loading to boundary condition

RESPONSE SPECTRUM ANALYSIS USING ETABS 2015 SOFTWARE

As per IS 1893: 2002 part I seismic zone and its soil type considered in the response spectrum responses using ETABS 2015. Loading and modal combination will be specified from some available options in the analysis. Response spectrums have three directional local co ordinate systems that define excitation angles. According to code there is one sealing factor that defines while inputting the response spectrum either in X and Y direction.

$$SealingFactor = 1/2 \times I/R \times g$$

If base shear V_b is lesser than the static analyzed base shear V. we should impact sealing factor which is equal to product of scale factor i.e.,

$$ScalingFactor = \frac{1}{2} \times \frac{I}{R} \times g \times \frac{V}{Vb}$$

III. MODELING AND ANALYSIS

INTRODUCTION

In the present paper an action is made on the seismic behavior of the multistory building by using diaphragm and there discontinuities. On the intention a regular four story and eight story building have analyzed and modeled by response spectrum analysis using ETABS 2015.lateral load analysis as per the seismic code IS: 1893 (Part 1)-2002 is carried out for regular building with rigid diaphragm by varying heights and even for the discontinuous diaphragm later an effort is made to study the effect of seismic loads and comparative study between the response spectrum analysis for both X and Y direction.

DESCRIPTION OF BUILDING

Description of building

Type of structure : Multi-storey R C frame structure
Occupancy : Residential Building
Number of stories : 5 (G+4) and 9(G+8)
Ground storey height : 3.0m
Intermediate floor height : 3.0m
Type of Soil : medium soil
Site location : Chennai
Seismic zone : IV

Materials

M20-concrete
Fe-415 steel

Member dimensions

Column size : 230mm x 450mm and 230mm x 600mm (8 floor)
Slab thickness : 150mm and 250mm (flat plate)
Beam Size : 230mm x 450mm
Wall thickness : 230mm

Live load

Live load on floor/roof : $3kN/m^2$
Floor finishing load : $1.5kN/m^2$
Wall load : 15kN/m

LOAD COMBINATIONS

The following load combinations are considered in the analysis and designed as per IS 1893 (Part 1)-2002.

Table 1 load combination table as per IS code

Load Combination	Load Factors
Gravity analysis	1.5 (DL+LL)

Equivalent static analysis	1.2 (DL + LL ± EQ_X) 1.2 (DL + LL ± EQ_Y) 1.5 (DL ± EQ_X) 1.5 (DL ± EQ_Y) 0.9 DL ± 1.5EQ_X 0.9 DL ± 1.5EQ_Y
Response spectrum analysis	1.2 (DL+ LL ± RS_Y) 1.2 (DL+ LL ± RS_X) 1.5 (DL ± RS_X) 1.5 (DL ± RS_Y)

Where, DL is Dead load and LL is Live load, EQ_X and EQ_Y are Earthquake loads in the X and Y- directions, respectively, RS_X and RS_Y are Earthquake Spectrum in the X- and Y- directions, respectively.
Modeling is done for four story building with 0% and 10% diaphragm discontinuity as shown in the fig 1 and 2 in 3D model

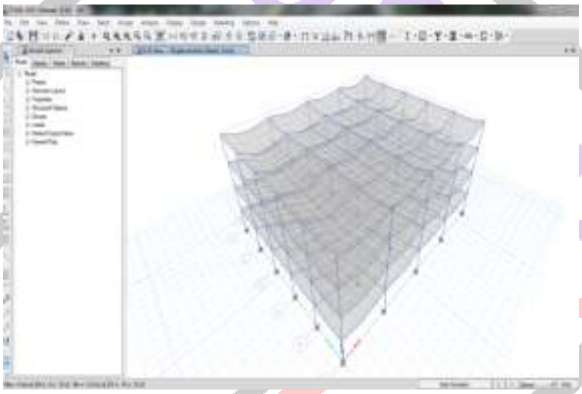

Fig 1: 3D View for four Story Building with 0% Diaphragm Discontinuity

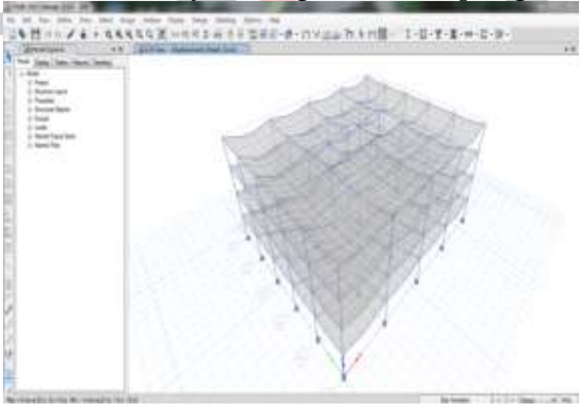

Fig 2: 3D View for Four Story Building with 10% Diaphragm Discontinuity

Modeling is done for four story building with 20% and 30% diaphragm discontinuity as shown in the fig 3 and 4 in 3D model

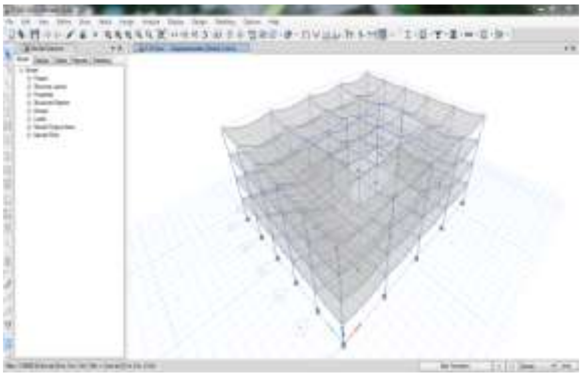

Fig 3: 3D View for Four Story Building with 20% Diaphragm Discontinuity

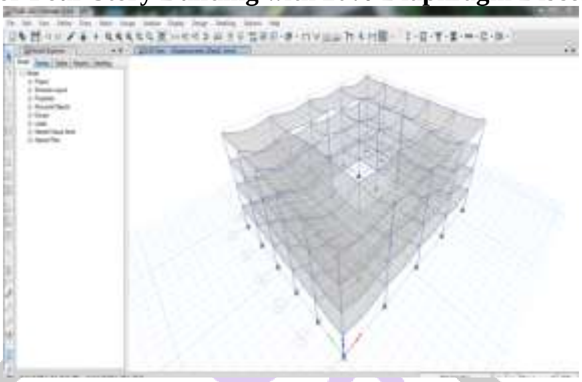

Fig 4: 3D View for Four Story Building with 30% Diaphragm Discontinuity

Modeling is done for four and eight story building with 0% and 10% diaphragm discontinuity as shown in the fig 5 and 6 with plan

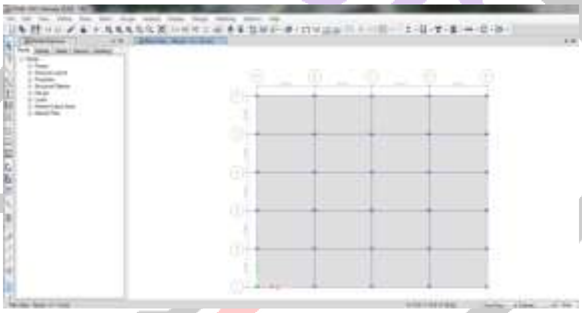

Fig 5: Plain view for Four and Eight Story Building with 0% Diaphragm Discontinuity

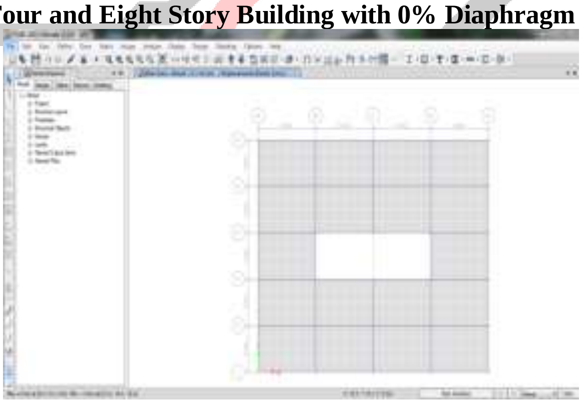

Fig 6:Plain view for Four and Eight Story Building with 10% Diaphragm Discontinuity

Modeling is done for four and eight story building with 20% and 30% diaphragm discontinuity as shown in the fig 7and 8 with plan

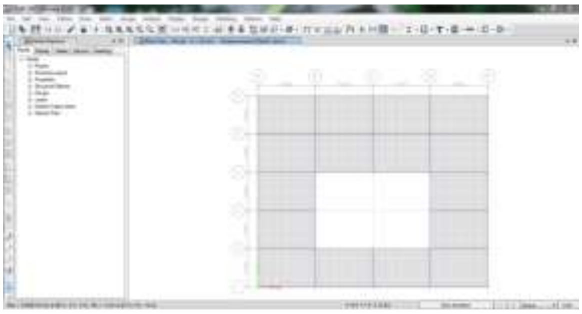

Fig 7: Plain view for Four and Eight Story Building with 20% Diaphragm Discontinuity

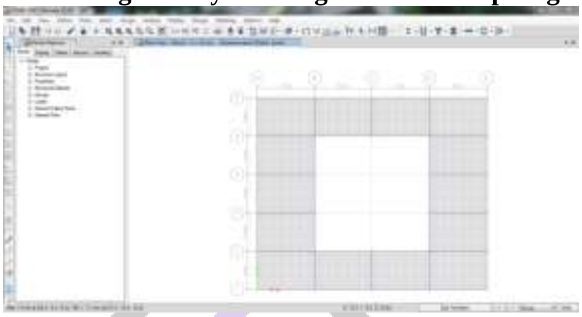

Fig 8: Plain view for Four and Eight Story Building with 30% Diaphragm Discontinuity

Modeling is done for eight story building with 0% and 10% diaphragm discontinuity as shown in the fig 9 and 10 in 3D model.

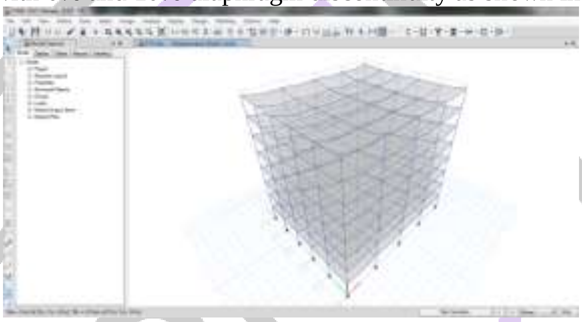

Fig 9: 3D View for Eight Story Building with 0% Diaphragm Discontinuity

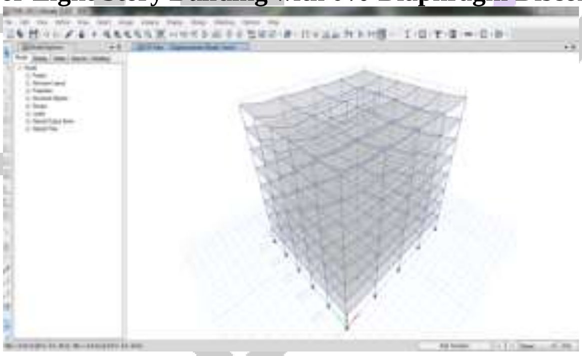

Fig 10: 3D View for Eight Story Building with 10% Diaphragm Discontinuity

Modeling is done for eight story building with 20% and 30% diaphragm discontinuity as shown in the fig 11 and 12 in 3D model

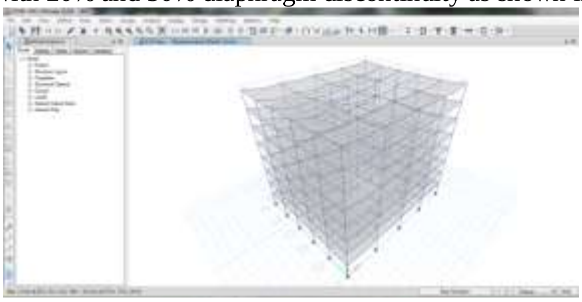

Fig 11: 3D View for Eight Story Building with 20% Diaphragm Discontinuity

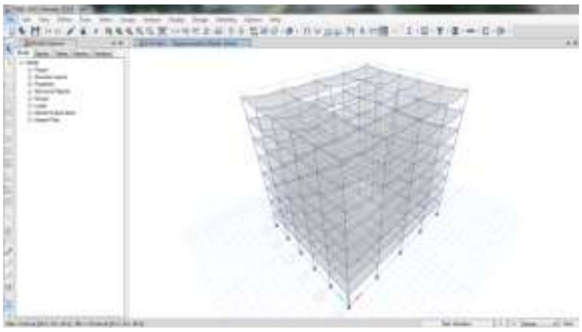

Fig 11: 3D View for Eight Story Building with 30% Diaphragm Discontinuity

Table 2 Comparison of Natural Time Period for 4 Story Buildings in Openings

Mode no	Natural Time Period in Seconds for 4 story			
	0% Discontinuity	10% Discontinuity	20% Discontinuity	30% Discontinuity
`1	1.563	1.533	1.495	1.454
2	1.181	1.178	1.169	1.159
3	1.096	1.071	1.058	1.046
4	0.529	0.518	0.505	0.491

In the table 6.2 there is detailing about time period for four story building with different openings, time period is more for no openings comparing to other openings in the four story building as shown in fig 6.3 of about 3% has decreased in each openings

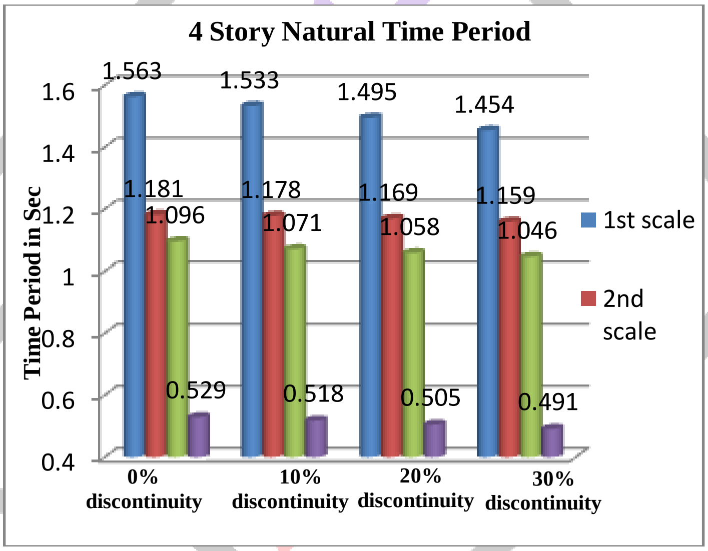

Chart 1: Comparison of Time Period with Different Openings in 4 Story Building

Table 3 Comparison of Natural Time Period for 8 Story Buildings in Openings

Mode no	Natural Time Period in Seconds for 8 story			
	0% Discontinuity	10% Discontinuity	20% Discontinuity	30% Discontinuity
1	3.02	2.96	2.89	2.83
2	2.326	2.31	2.3	2.23
3	2.19	2.15	2.132	2.117
4	1.008	0.99	0.96	0.941

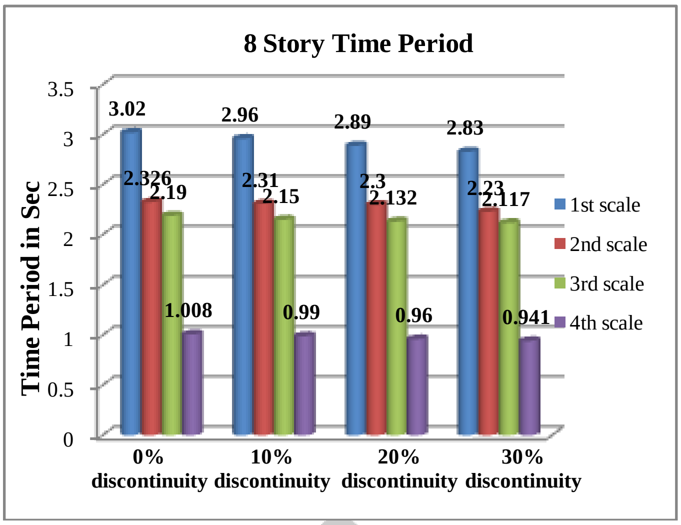

Chart 2:Comparison of Time Period with Different Openings in 4 Story Building

MAXIMUM STORY DISPLACEMENT

In the opening like 20% discontinuity deflected more of about 4.1% increased than other openings it is because of eccentricity loading in X direction as shown in table 6.14 fig 6.36 and 6.37.

Table 4 Comparison of Maximum Story Displacement 4 Story with Discontinuities

Natural Time Period in Seconds for 8 story				
Elevation in M	0% Discontinuity	10% Discontinuity	20% Discontinuity	30% Discontinuity
12	19.1	18.7	19.8	18.2
9	16.1	15.8	16.7	15.3
6	11.1	10.9	11.5	10.5
3	4.8	4.7	4.9	4.5
0	0	0	0	0

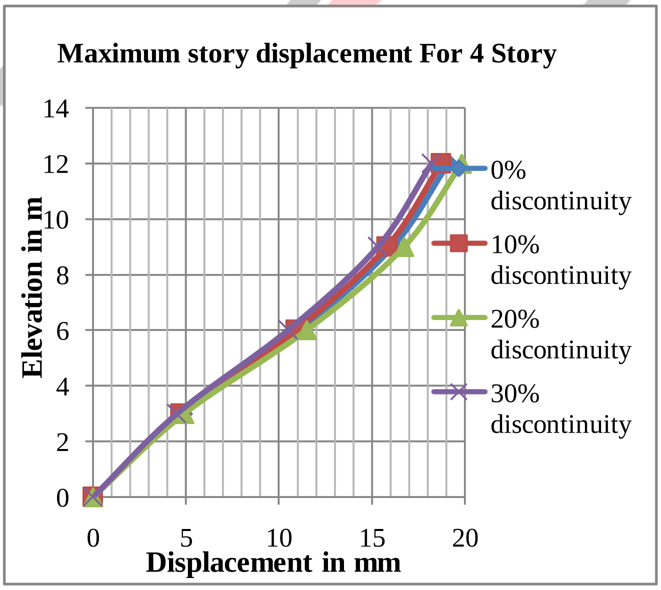

Chart 3: Maximum 4 Story Displacement in X Path with comparison in Different Discontinuity

In four story building the Y direction displacement is decreased of about 3% in top story in all other openings as shown in table 6.15 fig 6.38 and 6.39

Table 5 Comparison of Maximum 4 Story Displacement for 4 Story with discontinuities

Maximum Story Displacement in Y Direction For Different Discontinuities				
Elevation in M	0% Discontinuity	10% Discontinuity	20% Discontinuity	30% Discontinuity
12	26.9	26.4	25.7	25
9	23.3	22.8	22.3	21.6
6	17	16.7	16.3	15.8
3	8.6	8.4	8.2	7.9
0	0	0	0	0

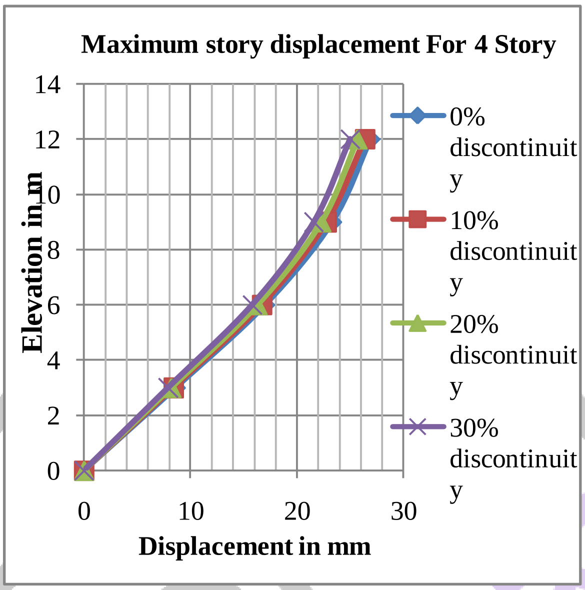

Chart 4: Comparison for Maximum 4 Story Displacement in Response Y

In the opening like 20% discontinuity deflected more of about 7.1% increased for top story than other openings in same top story it is because of eccentricity loading in X direction as shown in table 6.16 fig 6.40 and 6.41

Table 6 Comparison of Maximum Story Displacement for 8 Story with discontinuities in X Direction

Maximum Story Displacement in X Direction For Different Discontinuities				
Elevation in M	0% Discontinuity	10% Discontinuity	20% Discontinuity	30% Discontinuity
24	38.9	38.1	40.9	37.7
21	37.1	36.4	38.9	35.8
18	34.1	33.4	35.7	32.8
15	29.9	29.3	31.3	28.7
12	24.9	24.4	26	23.8
9	18.9	18.5	19.7	18
6	12.2	11.9	12.6	11.5
3	5	4.9	5.1	4.6
0	0	0	0	0

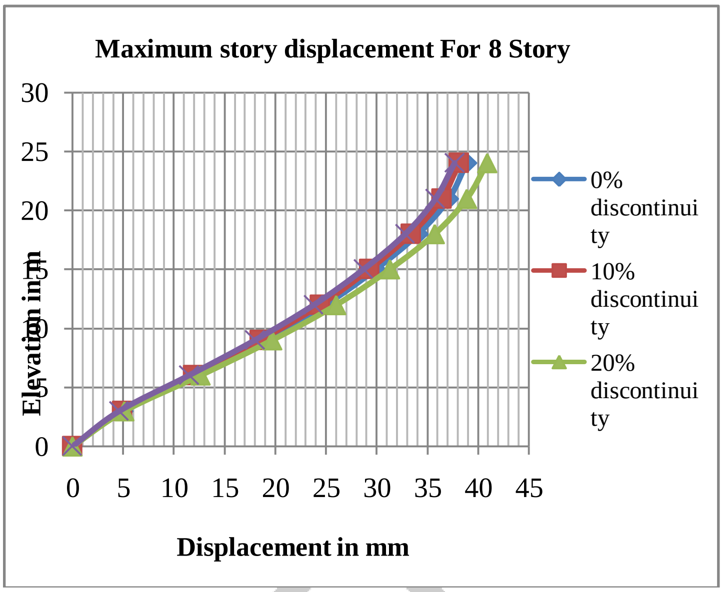

Chart 5: Similarity of Maximum Story Displacement for Response Y

In eight story building the Y direction displacement is decreased of about 2.3% in top story in all other openings as shown in table 6.17 fig 6.42 and 6.43

Table 7 Comparison of Maximum Story Displacement for 8 Story with discontinuities in Y Direction

Maximum Story Displacement in Y Direction For Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
24	52.9	52.1	51.1	49.9
21	50.6	49.8	48.9	47.7
18	46.7	45.9	45	43.9
15	41.4	40.7	39.8	38.8
12	34.9	34.2	33.5	32.6
9	27.2	26.7	26.1	25.4
6	18.4	18	17.6	17.2
3	8.8	8.6	8.4	8.1
0	0	0	0	0

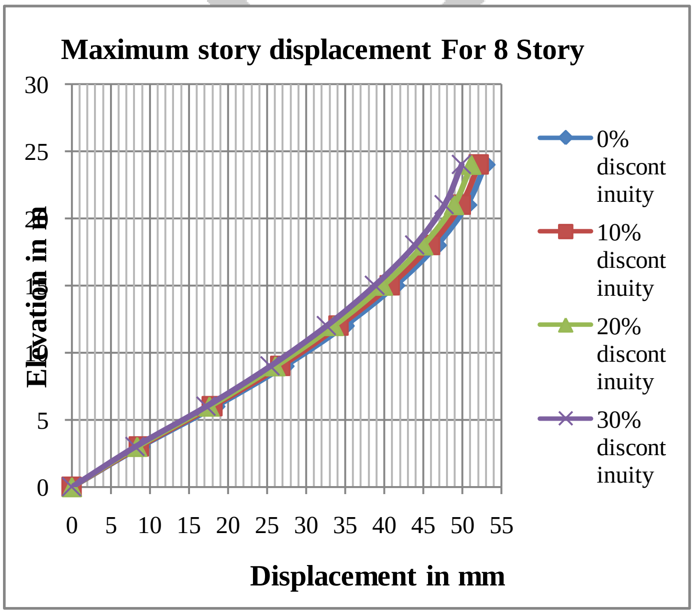

Chart 6: Similarity of Maximum 8 Story Displacement in Response y

MAXIMUM STORY DRIFT

In the opening like 20% discontinuity deflected more of about 7.9% increased than other openings in four stories building it is because of eccentricity loading in X direction as shown in table 6.24 figs 6.58 and 6.59

Table 8 Comparison of Story Drift for Different Discontinuity in X

Optimum Story Drift in X Direction For Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
12	0.001066	0.001043	0.001114	0.001039
9	0.001722	0.001688	0.001796	0.001663
6	0.002123	0.002079	0.002205	0.002029
3	0.001602	0.001561	0.00164	0.001485
0	0	0	0	0

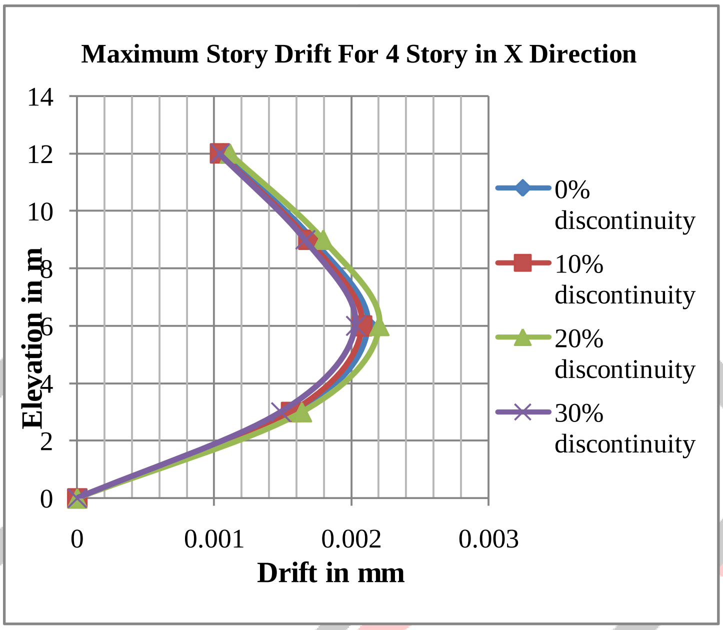

Chart 7:Comparison of Optimum Story Drift for 4 Story in Directory X

In four story building the Y direction displacement is decreased of about 3% in all other openings as shown in table 6.25 fig 6.60 and 6.61

Table 9 Comparison of Maximum Story Drift for Different Discontinuity in Y

Maximum Story Drift in Y Direction For Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
12	0.001444	0.001413	0.001371	0.001324
9	0.002292	0.002251	0.002193	0.002127
6	0.002847	0.0028	0.002734	0.002657
3	0.002875	0.002803	0.002726	0.002638
0	0	0	0	0

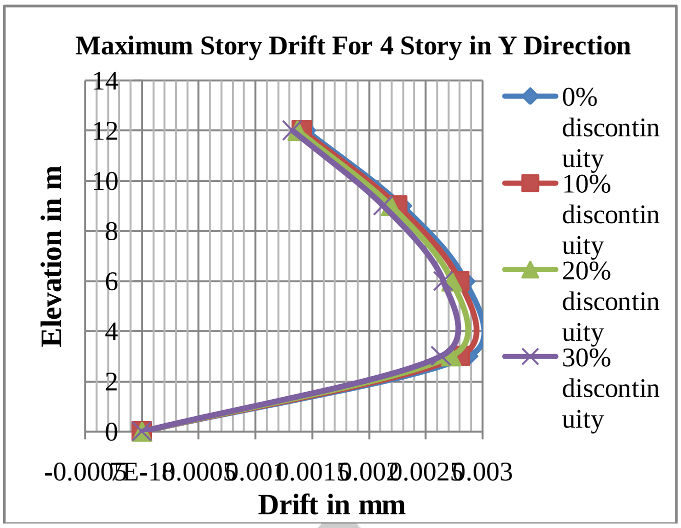

Chart 8:Similarity of Optimum Story Drift for 4 Story in Directory Y

In the opening like 20% discontinuity deflected more of about 8.5% increased than other openings in eight stories buildings it is because of eccentricity loading in X direction as shown in table 6.26 figs 6.62 and 6.63

Table 10 Comparison of Optimum Story Drift for Different Discontinuity in X Direction for 8 Story

Story Drift in X Direction For Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
24	0.000746	0.000735	0.000805	0.000767
21	0.001254	0.001233	0.001333	0.001249
18	0.001624	0.001595	0.001716	0.001597
15	0.001864	0.001828	0.001963	0.001819
12	0.002066	0.002026	0.002171	0.002004
9	0.002282	0.002236	0.002391	0.0022
6	0.002391	0.00234	0.002493	0.00228
3	0.001666	0.001624	0.001715	0.001542
0	0	0	0	0

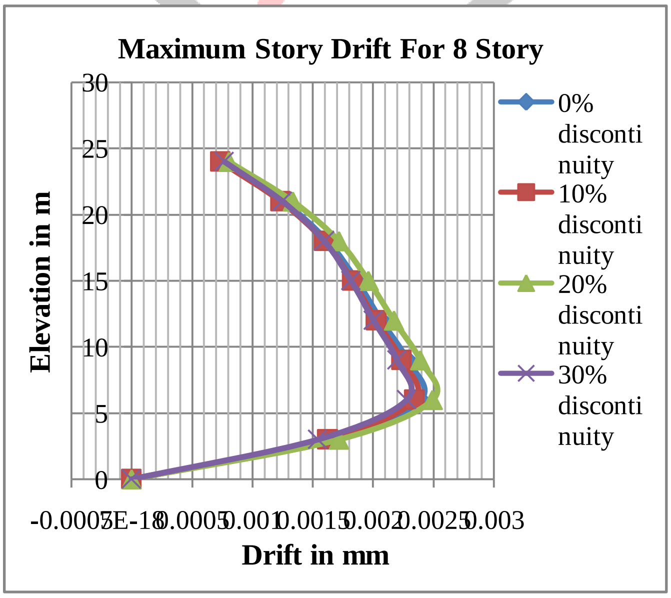

Chart 9:Similarity of Optimum Story Drift for 4 Story in Response X with Discontinuity

In four story building the Y direction displacement is decreased of about 2.5% in all other openings as shown in table 6.27 fig 6.64 and 6.65

Table 11 Optimum Story Drift for Different Discontinuity in Y Direction for 8 Story

Optimum Story Drift in Y Direction For Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
24	0.000911	0.00091	0.000904	0.000894
21	0.001602	0.001589	0.001568	0.00154
18	0.002096	0.002072	0.002039	0.001998
15	0.002418	0.002386	0.002344	0.002292
12	0.002679	0.002639	0.002589	0.002528
9	0.002961	0.002913	0.002854	0.002784
6	0.003222	0.003165	0.003098	0.003018
3	0.002926	0.002853	0.002785	0.002706
0	0	0	0	0

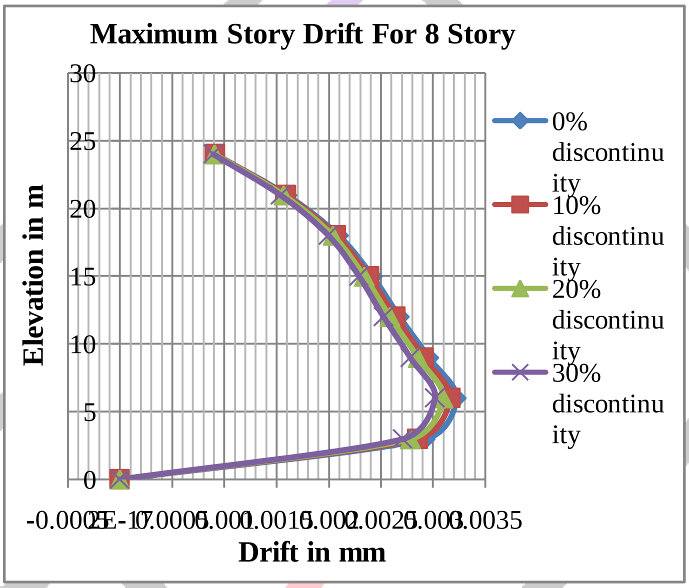

Chart 10: Similarity of Highest Story Drift for 8 Story in Response Y with Discontinuity

STORY BASE SHEARS

In four story building the X direction base shear is decreased of about 7.8% in all openings as shown in table 6.34 fig 6.78 and 6.79

Table 12 Comparison of base Shear for 4 Story in X Direction with Openings

Base Shear in kN Response in X Direction with Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
12	568.837	547.811	503.947	465.142
9	939.190	907.713	835.043	771.021
6	1198.147	1159.275	1066.489	984.828
3	1358.263	1312.595	1206.329	1112.689
0	0	0	0	0

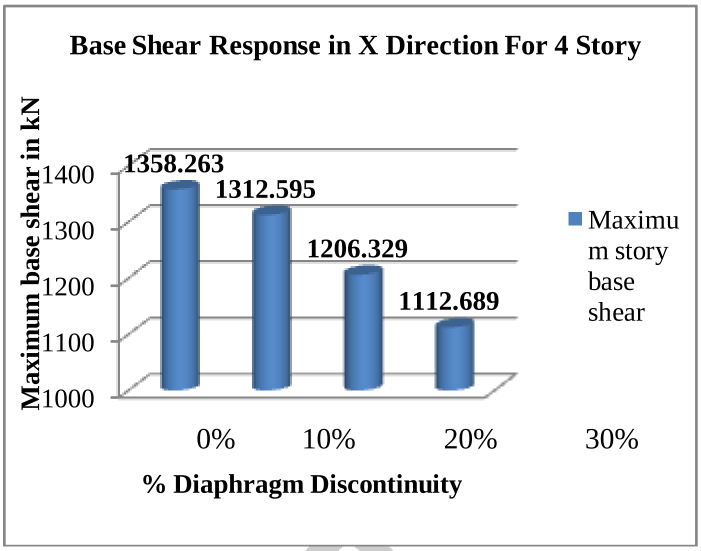

Chart 11: Comparison of Base Shear for 4 Story in X Directions

In four story building the Y direction base shear is decreased of about 4.5% in all openings as shown in table 6.35 fig 6.80 and 6.81

Table 13 Comparison of base Shear for 4 Story in Y Direction with Openings

Base Shear in kN Response in Y Direction with Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
12	430.6274	414.2465	385.7124	356.7028
9	681.604	658.5243	616.8112	574.0333
6	845.5292	819.1333	769.7492	718.7806
3	992.63	959.9176	900.3432	839.0834
0	0	0	0	0

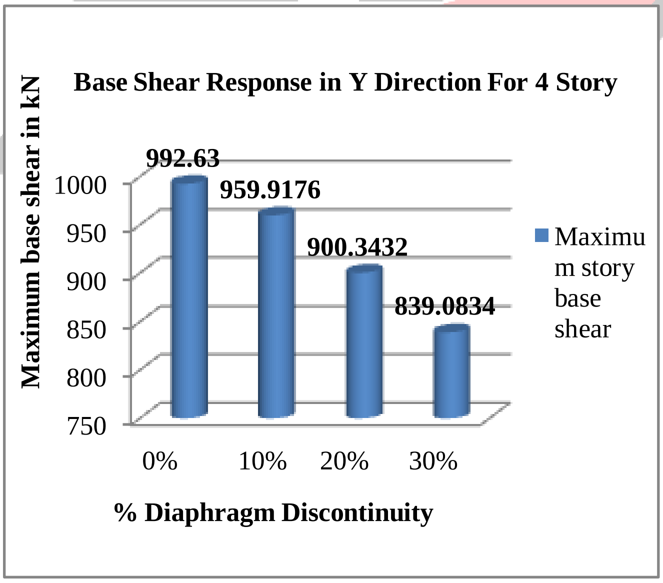

Chart 12:Comparison of Base Shear for 4 Story in Y Directions

In eight story building the X direction base shear is decreased of about 8% in all openings as shown in table 6.36 fig 6.82 and 6.83

Table 14 Comparison of base Shear for 8 Story in X Direction with Openings

Base Shear in kN Response in X Direction with Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
24	357.781	346.662	319.647	296.266
21	649.650	629.207	579.013	535.461
18	843.372	816.081	749.208	691.095
15	961.913	929.822	851.865	784.112
12	1065.336	1029.229	942.194	866.631
9	1191.126	1150.937	1054.121	970.151
6	1311.948	1268.081	1162.008	1070.031
3	1373.347	1327.509	1216.397	1120.041
0	0.000	0.000	0.000	0.000

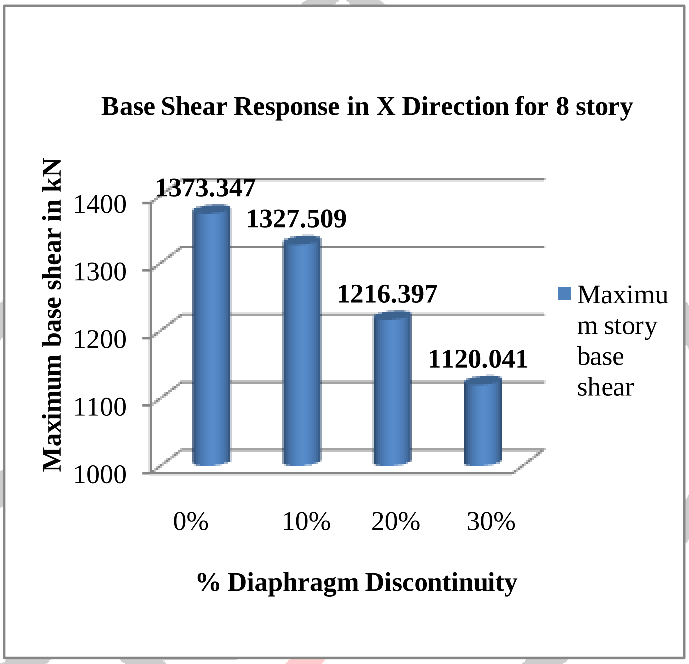

Chart 13:Comparison of Base Shear for 8 Story in X Directions

In eight story building the Y direction base shear is decreased of about 6.4% in all openings as shown in table 6.34 fig 6.84 and 6.85

Table 15 Comparison of base Shear for 8 Story in Y Direction with Openings

Base Shear in kN Response in Y Direction with Different Discontinuities				
Elevation in M	**0% Discontinuity**	**10% Discontinuity**	**20% Discontinuity**	**30% Discontinuity**
24	245.878	238.268	224.753	210.726
21	453.395	439.067	413.982	387.984
18	599.021	579.525	545.997	511.295
15	693.845	670.669	631.390	590.787
12	772.423	746.319	702.325	656.878
9	860.452	831.476	782.512	731.933
6	947.156	915.450	861.744	806.251
3	998.642	965.156	908.633	850.221
0	0.000	0.000	0.000	0.000

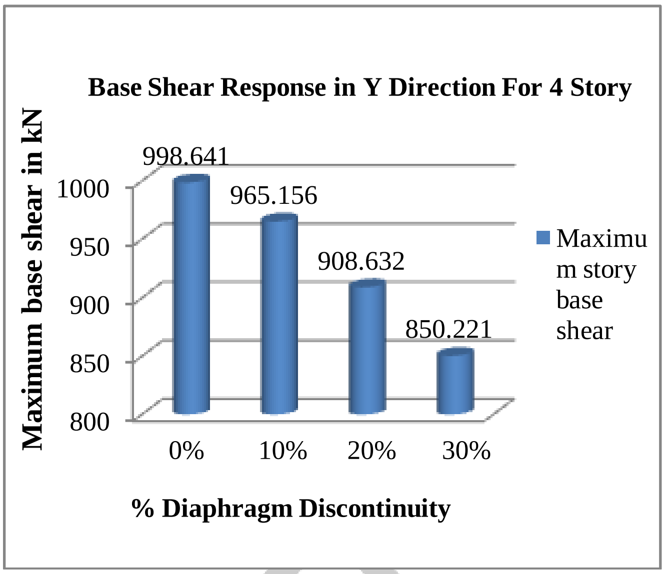

Chart 14: Comparison of Base Shear for 8 Story in Y Directions

IV. CONCLUSION

- Results procured from the response spectrum method of analysis has got preceding values in both eight and for four story building
- Natural time period is getting decreased as the percentage of openings
- Maximum displacement for four and eight story building shown lesser displacement value in stiffness diaphragm compared to no diaphragm and with all types of openings, 20% opening deflected more compared with other condition and this is due to eccentricity loading in X direction where as in Y direction openings there is a gradual decrease in displacement of about 3%
- Maximum drift for four and eight story building shown lesser drift value in stiffness diaphragm compared to no diaphragm, 20% opening deflected more compared to other because of eccentricity loading in X direction where as in Y direction openings there is a gradual decrease in drift of about 2.5%
- In four and eight story building with stiffness diaphragm shown more story shear in response X and Y direction. Building with 20% opening shows decreasing story shear value of about 7.8% in response X and 4.5% in response Y, in flat plate the values are decreasing in nature.
- These all results shows building with stiffness diaphragm are better to use in all multi story building for those areas which are prone to earthquake. 20% of opening is a better one when compared other condition.
- Optimum percentage 20% o opening or Discontinuity of stiffness diaphragm can be used in the seismic prone RC multistory building, even the number of story height increases the same comparison results of 20% openings can be utilized
- Discontinuity in diaphragm shows that optimum percentageof openings will with stand the seismic forces in earthquake areas

Scope of the Future Study

- The same data of four and eight story building can be analyzed in non linear method of analysis.
- 20% openings can be used in the different higher story buildings so that it decreases the seismic forces in any earthquake affected areas
- Openings in the RC buildings will control the seismic forces, more the openings lesser will be displacement, time period.

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