Seismic Effects on Buildings with Data Centre Loads

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***Abstract*— The focus of this study is on seismic effect of building housing Data centre. The seismic results of "Data Centre Buildings", having heavy imposed loading due to equipments is compared with "Normal buildings" having normal office loading. Structurally Data Centre buildings supports heavy loads imposed on it. As they support systems such as telecommunication racks which houses computer and storage components. Data centre contains sensitive telecommunication systems, computer systems and storage components in an environment which provides controlled air conditioning at desired levels along with required electrical equipments with highest level of fire protection. Power supply and data communication systems are redundant**

Structural layout of Data centre building depends on factors such as architectural constraints, large column free areas to facilitate performance of HVAC systems, accommodation of optimum number of racks and loading as per TIA 942 guidelines, Tier level defined by Uptime.

Data centre Building have raised floors which is created to provide a dedicated space for electrical, mechanical, telecommunication services to be accommodated to connect various equipments. Structurally the data centre area is provided with sunken slab so that the space within the false floor act as cold plenum whereas the false ceiling provide the hot air plenum. In order to have obstruction free hot air plenum beam depths are restricted in server areas of Data centre buildings. Minimum height clearance is required between the false floor and false ceiling. Data centers are to be given special attention for Seismic design so as to have effective lateral force resisting system.

"Etabs 2016" is used as analysis tool for this study. Data Centre Buildings with heavy loading and normal buildings with normal loading of G+3 storied of same configurations is modeled and there structural parameters such as lateral displacements and storey shears are compared.

Keywords*— *data centre; static analysis; dynamic analysis

I. INTRODUCTION

A data Centre building is basically IT layout of the equipment in the room (or rooms), Equipment placement and its layout is important in a data centre building and is critical to its efficiency. Structural planning that is location and sizes of columns and beams plays critical role for performance of these precision equipments. Structural layout of data centre buildings are planned from its conception stage itself, keeping in mind the architectural and space constraints and to achieve optimal number of racks and forming minimal obstructions. Location of columns are provided as far as possible on the boundary of data centre for relatively smaller rooms, so that equipment area is free of columns. For larger server rooms if columns are unavoidable from point of view of structural support then room plan is to be provided as if columns do not exist and laid out directly on the rack position in a row preferably at the row end, in the process some of the racks may be sacrificed so that columns are accommodated. In all cases columns are to be laid out so as to avoid aisles, access ways, fire escapes etc. Thus coordinated Architectural and structural layout will have huge impact on number of racks in data centers. In most of the data centers False Floors and Ceilings are used as cold air plenum and hot air plenum respectively necessitating the raised floors. Since data centers are with false floors the structural system have the drop of levels between slab of server halls and other areas.

This study compares the structural aspects of a data centre buildings with heavy loads with that of normal buildings with normal loading of same geometrical configurations. Using Etabs 2016 as analysis tool, 3D analytical model of two numbers of G+3 storied data centre buildings are generated and again same models are considered as normal buildings with normal loading. Analytical model of data centre buildings and normal buildings includes all the structural characteristics such as strength stiffness and mass. From the studies it has been established that the lateral storey displacements are within the limits' specified by the code.

II. ANALYTICAL MODELLING

Data centre building considered have electrical, UPS and transformer rooms at ground floor and server rooms in first and second floor along with corridors on either side and office/administrative rooms attached to one of the corridor. Depths of beams inside the server room are kept shallower to avoid hindrance to hot air plenum in ceilings. Floor of the server area is sunken to provide the space to act as cold air plenum. Peripheral beams of server area supports the sunken slab of server room at lower level on one side and on the other side the slab of corridor at higher level, this necessitates the increase in depth of these peripheral beams. Boundary wall of server room is considered as RCC wall of 300 mm thick.

The stiffness and mass of the walls are included. The height of Ground floor is considered as 5.65 m and typical floor height of data centre floor is 4.25 m. Typical floor plans of a data centre buildings DCB-01 & DCB-02 are shown in Fig.1and Fig.3 respectively and their corresponding 3D views are shown in Fig.2 and Fig.4

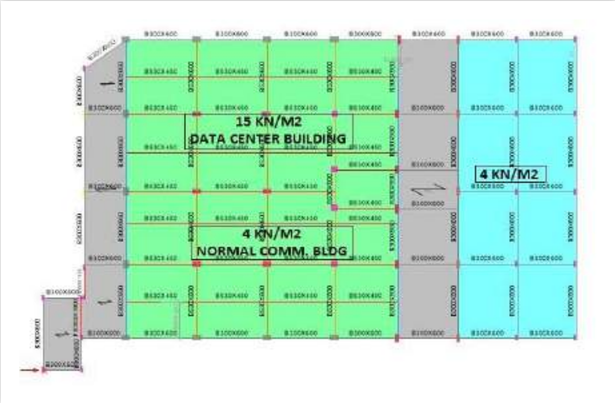

Figure 1.Typical floor plan (DCB-01)

The three dimensional view of the typical data centre building is shown in Fig.2.

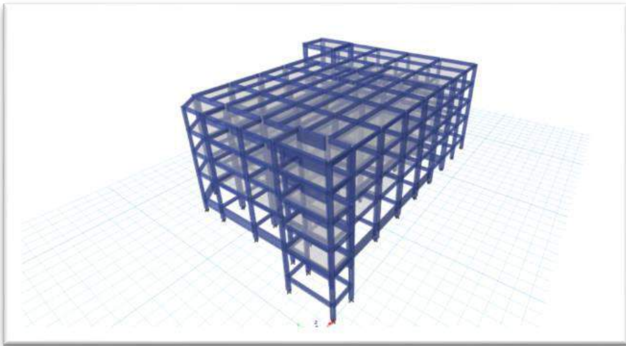

Figure 2.Three dimensional view (DCB-01)

ETABS is a finite element analysis tool for performing two and three-dimensional linear and nonlinear static and dynamic analysis on structures with a special emphasis on dynamic earthquake loading. The program used for this study, ETABS 2016 which is Nonlinear general purpose finite element software having capability to perform static and dynamic analysis of two and three dimensional linear and non linear analysis.

The design parameters are shown in Table I.

TABLE I. DESIGN PARAMETERS

Type of Load	Intensity
Dead Loads	
Masonry	20.0kN/m^3
Concrete	25.0kN/m^3
Live Loads	4.0kN/m^2
Floor Load	15.0kN/m^2
Roof Load	2.0kN/m^2
Floor Finishes	1.0kN/m^2
Importance Factor	1.50
Response reduction factor	3.0

The member dimensions of data centre buildings are shown in Table II.

TABLE II. .MEMBER DIMENSIONS

Element	Dimension
Slabs	175 mm in server areas and 150mm in office area.
Beams	Peripheral beams of sever areas 300mm x 950 mm. Beams in hot air Plenum areas 530mmx450mm
Columns	600mm x 900mm (Server room pheripheral). 530mm x 900mm (Server room interior).
Grade of Concete and Steel	M30 concrete, Fe 500 steel

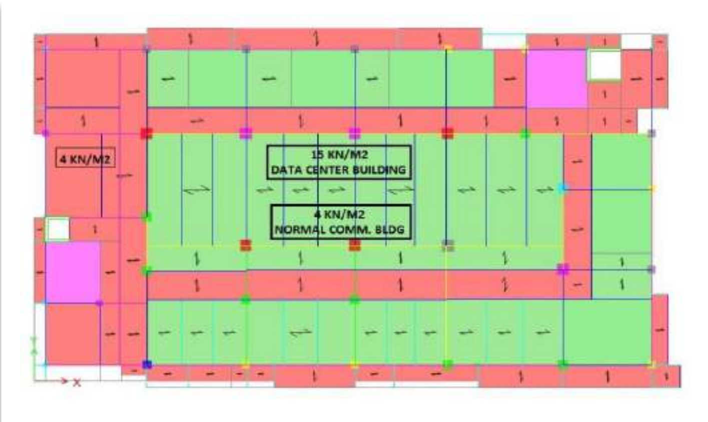

Figure 3.Three dimensional view (DCB-02)

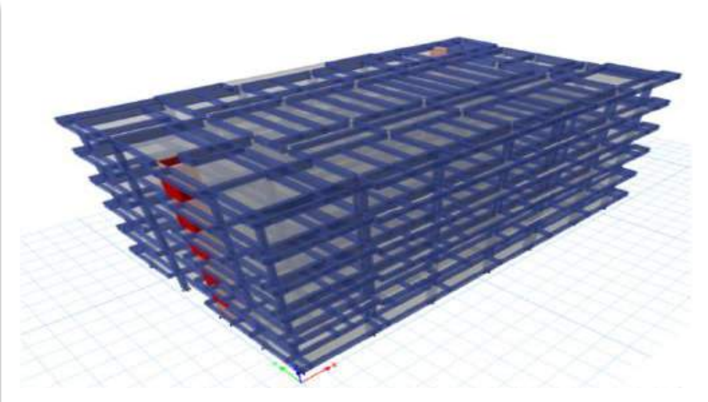

Figure 4.Three dimensional view (DCB-02)

III. RESULTS: DCB-01(DATA CENTRE LOADING)

A. *Displacements(mm)*

The results from analysis comparing the DCB-01 Data centre building with that of normal building is done in the form of the displacements and Storey shears for static and Response spectrum methods with eccentricity and without eccentricity.

The displacements in X direction with and without eccentricity are shown in Table III.

TABLE III. DISPLACEMENTS IN X DIRECTION WITH AND WITHOUT ECCENTRICITY FOR DATA CENTRE BUILDING DCB-01

Displacement: X direction				
Storey	Static		Response Spectrum	
	EQX-ey-0	EQX-ey-5%	RSX-ey-0	RSX ey-5%
6	19.78	20.91	6.206	6.562
5	18.675	19.44	5.984	6.332
4	16.029	16.742	5.243	5.55
3	12.009	12.6	4.045	4.285
2	6.99	7.4	2.426	2.575
1	1.147	1.155	0.402	0.411
0	0	0	0	0

Displacements in Y-direction with and without eccentricity for data centre building DCB-01 are given in Table IV.

TABLE IV. DISPLACEMENTSIN Y DIRECTION WITH AND WITHOUT ECCENTRICITY FOR DATA CENTRE BUILDING DCB-01

Displacement: Y direction				
Storey	Static		Response Spectrum	
	EQY-ex-0	*EQY ex-5%*	*RSY-ex-0*	*RSY ex-5%*
6	15.96	17.684	5.474	6.474
5	14.967	17.925	5.221	6.189
4	13.406	15.749	4.781	5.651
3	10.77	12.193	3.958	4.651
2	7.239	7.556	2.725	3.167
1	1.39	1.268	0.52	0.578
0	0	0	0	0

A bar graph showing displacement in X direction is shown in Fig.5.

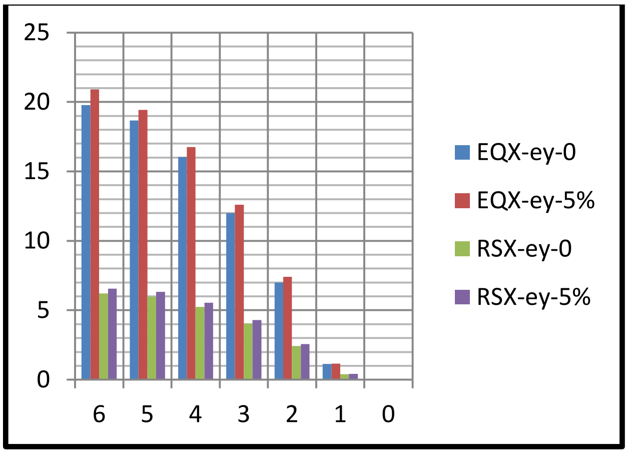

Figure 5.Bar graph of displacement in X-direction for data centre building DCB-01

Fig.6 shows displacements in mm for X-direction for Static and Response spectrum Method with and without eccentricity.

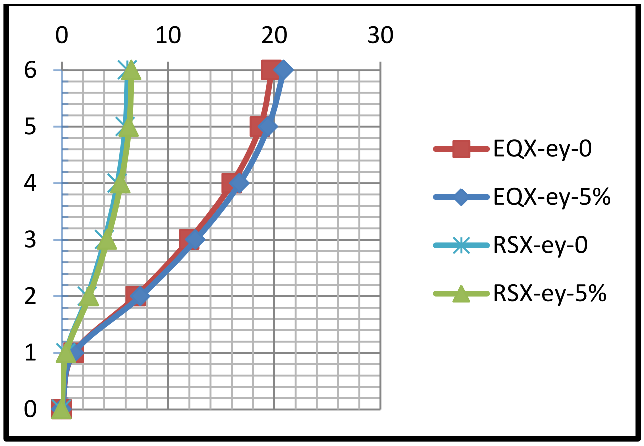

Figure 6.Displacements in mm for X direction static and response spectrum with and without eccentricity for data centre building DCB-01

A bar graph showing displacement in Y direction is shown in Fig.7.

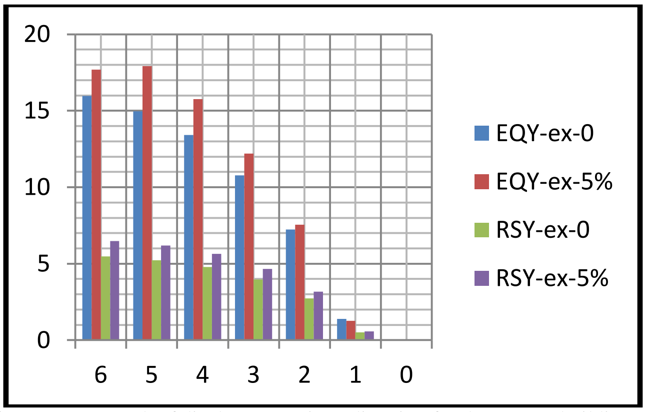

Figure 7.Bar Graph of displacements in Y direction for data centre building DCB-01

Fig.8 shows displacements in mm for Y-direction for Static and Response spectrum Method with and without eccentricity.

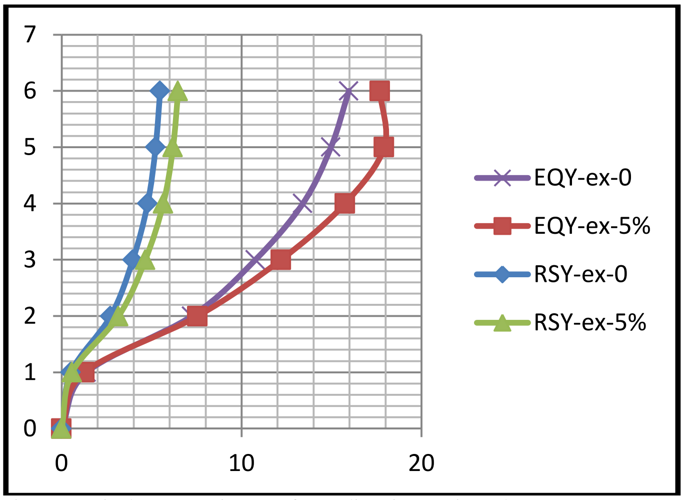

Figure 8. Displacements in mm for Y direction static and response spectrum with and without eccentricity for data centre building DCB-01

B. Storey Forces and Base Shear

Storey and base shear are calculated in Kilo Newton for X and Y directions for static and response spectrum method with and without eccentricity for Data Centre building DCB-01 and tabulated as follows. Table V. shows storey shear in X-direction with and without eccentricity.

TABLE V. STOREY SHEAR X-DIRECTION FOR DATA CENTRE BUILDING DCB-01

Storey Shear: X direction				
Story	Static		Response Spectrum	
	EQX-ey-0	EQX-ey-5%	RSX-ey-0	RSX ey-5%
6	59.7	59.7	20.4	20.4
5	882.0	882.0	271.3	271.3
4	1682.6	1682.6	517.6	517.6
3	2135.5	2135.5	691.6	691.6
2	2341.8	2341.8	832.3	832.3
1	2347.3	2347.3	838.0	838.0

A bar graph of storey shear in X-direction is shown in Fig.9.

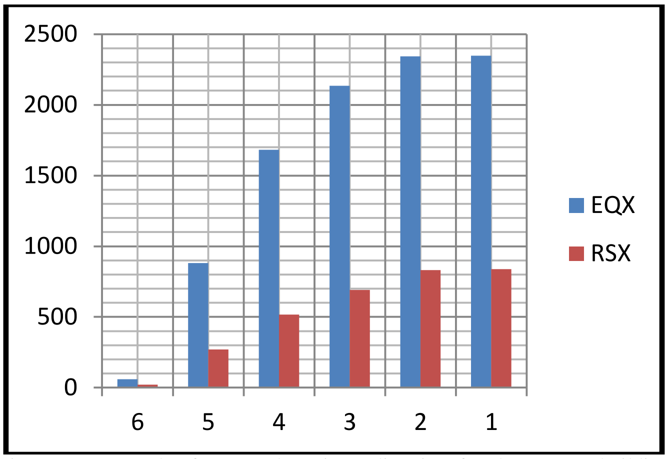

Figure 9.Bar graph of storey shear in X-direction for data centre building DCB-01

Fig.10 shows storey shear for X-direction for Static and Response spectrum Method with and without eccentricity.

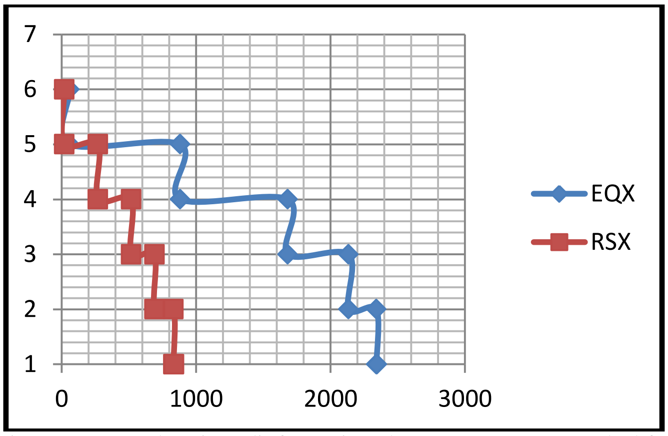

Figure10. Storey shear in X-dir for Static and Response spectrum Method for data centre building DCB-01

A bar graph of storey shear in Y-direction is shown in Fig.11.

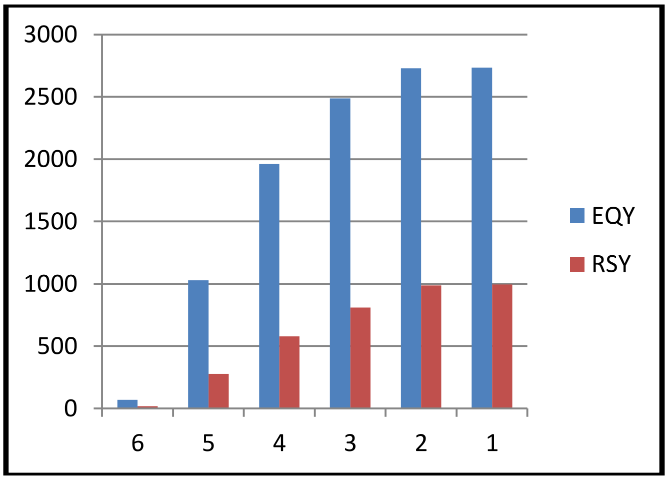

Figure 11.Storey shear in Y-direction for data centre building DCB-01

Fig.12 shows storey shear for Y-direction for Static and Response spectrum Method with and without eccentricity.

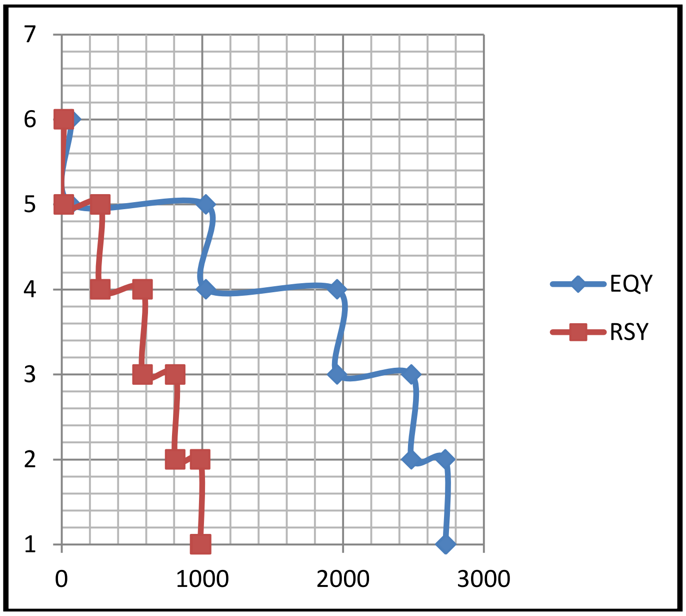

Figure 12. Storey shear in Y-dir for static and response spectrum method for data centre building DCB-01

IV. RESULTS: DCB-01(NORMAL LOADING)

A. Displacements(mm)

For normal buildings displacements in mm is calculated for X and Y directions for static and response spectrum method for with and without eccentricity. Displacements in X-direction for normal buildings with and without eccentricity are given in Table VI.

TABLE VI. DISPLACEMENT IN X DIRECTION FOR NORMAL BUILDING DCB-01

Displacement: X direction				
Storey	Static		Response Spectrum	
	EQX-ey-0	EQX-ey-5%	RSX-ey-0	RSX ey-5%
6	17.023	17.903	5.252	5.546
5	15.999	16.889	5.024	5.309
4	13.619	14.393	4.367	4.619
3	10.138	10.728	3.345	3.541
2	5.879	6.235	1.994	2.115
1	0.963	0.968	0.337	0.346
0	0	0	0	0

Displacements in Y-direction for normal building with and without eccentricity are given in Table VII.

TABLE VII. DISPLACEMENT IN Y DIRECTION FOR NORMAL BUILDING DCB-01

Displacement: Y direction				
Storey	*Static*		*Response Spectrum*	
	EQY-ex-0	*EQY ex-5%*	*RSY-ex-0*	*RSY ex-5%*
6	14.319	15.918	4.652	5.143
5	13.891	16.533	4.975	5.793
4	12.127	14.423	4.436	5.161
3	9.356	11.099	3.515	4.081
2	5.802	6.84	2.222	2.568
1	1.085	1.104	0.364	0.42
0	0	0	0	0

A bar graph showing displacement in X direction for normal building is shown in Fig.13.

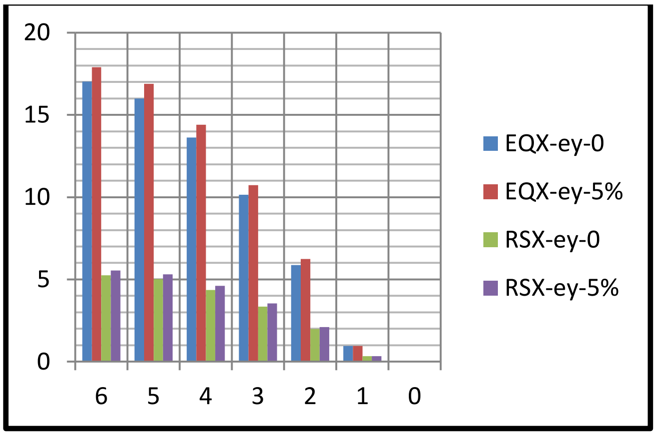

Figure 13. Bar graph of displacement in X-direction for normal building DCB-01

Fig.14 shows displacements in mm for X-direction for Static and Response spectrum Method with and without eccentricity for normal building.

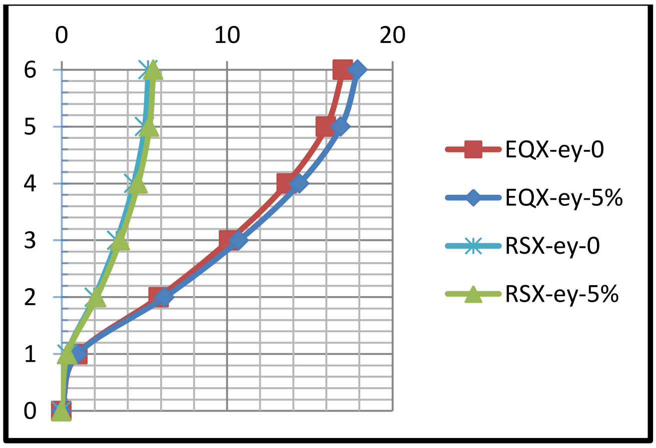

Figure 14. Displacements in mm for X-direction Static and Response spectrum Method with and without eccentricity for normal building DCB-01

A bar graph showing displacement in Y direction for normal building is shown in Fig.15.

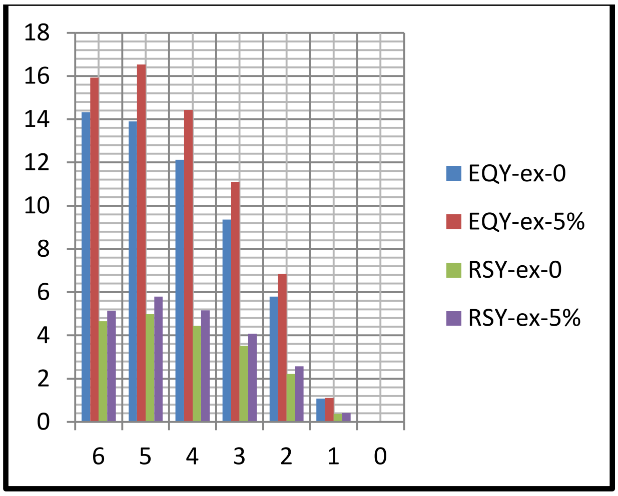

Figure 15. Bar graph of displacement in Y-direction for normal building DCB-01

Fig.16 shows displacements in mm for Y-direction for Static and Response spectrum Method with and without eccentricity for normal building.

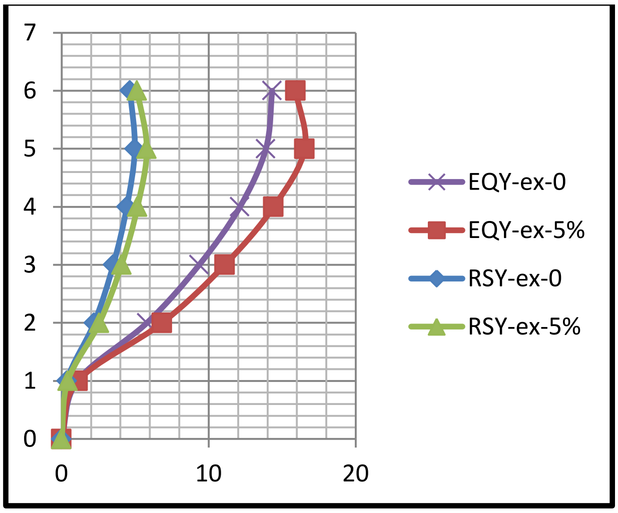

Figure 16. Displacements in mm for Y-direction Static and Response spectrum Method with and without eccentricity for normal building DCB-01

B. Storey Forces and Base Shear

Storey and base shear are calculated in Kilo Newton for X and Y directions for static and response spectrum method with and without eccentricity for normal building and tabulated as follows. Table VIII .shows storey shear in X-direction with and without eccentricity.

TABLE VIII. STOREY SHEAR IN X DIRECTION FOR NORMAL BUILDING DCB-01

Storey Shear: X direction				
Storey	Static		Response Spectrum	
	EQX-ey-0	EQX-ey-5%	RSX-ey-0	RSX ey-5%
6	63.4	63.4	20.5	20.5
5	832.8	832.8	240.0	240.0
4	1452.2	1452.2	430.8	430.8
3	1802.7	1802.7	571.7	571.7
2	1963.4	1963.4	678.4	678.4
1	1969.8	1969.8	684.6	684.6

Table IX. shows storey shears in Y-direction with and without eccentricity for normal building DCB-01.

TABLE IX. STOREY SHEAR IN Y DIECTION FOR NORMAL BUILDING DCB-01

Storey Shear: Y direction				
Storey	*Static*		*Response Spectrum*	
	EQY-ex-0	*EQY ex-5%*	*RSY-ex-0*	*RSY ex-5%*
6	73.2	73.2	16.0	16.0
5	961.6	961.6	238.7	238.7
4	1676.8	1676.8	461.8	461.8
3	2081.5	2081.5	635.6	635.6
2	2267.1	2267.1	764.9	764.9
1	2274.5	2274.5	772.7	772.7

A bar graph showing storey shear in X direction for normal building is shown in Fig.17.

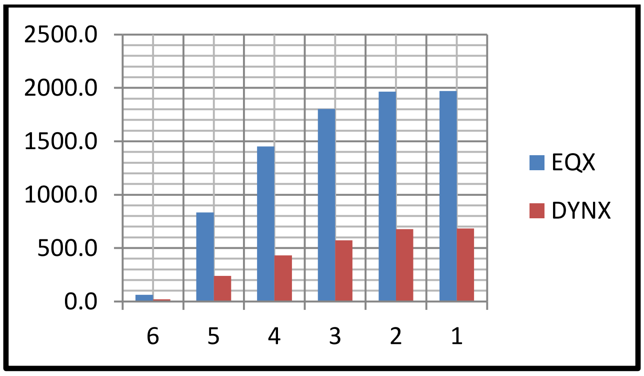

Figure 17. Bar graph of Storey shear in X-direction for normal building DCB-01

Fig.18 shows storey shear in normal building for X-direction for Static and Response spectrum Method with and without eccentricity.

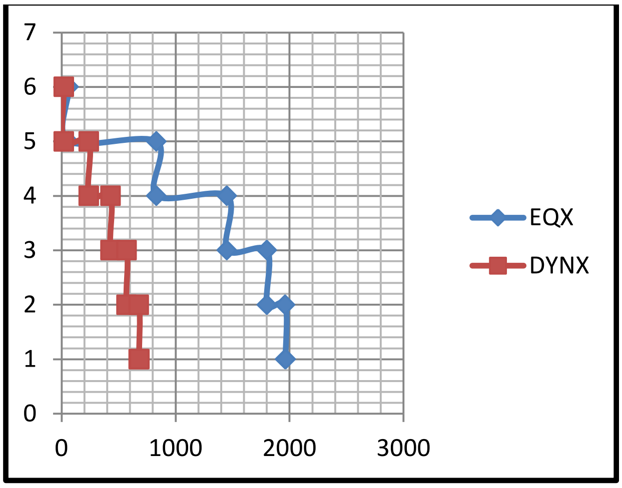

Figure 18. Storey shear in X-dir for static and response spectrum method for normal building DCB-01.

A bar graph showing storey shear in Y direction for normal building is shown in Fig.19.

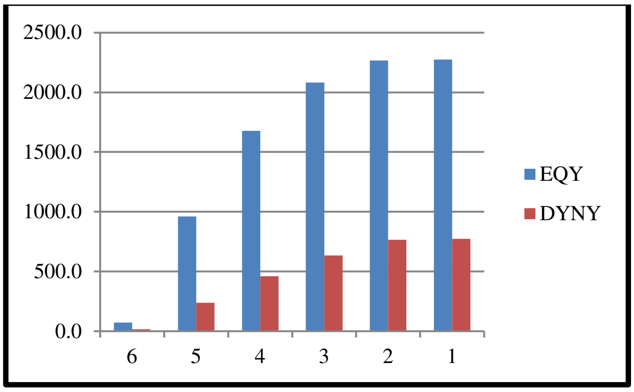

Figure 19. Bar graph of Storey shear in Y-direction for normal building DCB-01.

Fig.20 shows storey shear in normal building for Y-direction for Static and Response spectrum Method with and without eccentricity.

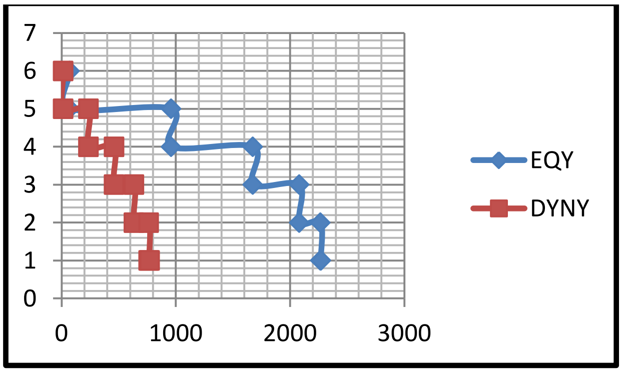

Figure 20. Storey shear in Y-direction for static and response spectrum method for normal building DCB-01

V. RESULTS: DCB-02(DATA CENTRE LOADING)

A. Displacements, Storey Shear and Base Shear

The results from analysis comparing the DCB-02 Data centre building with that of normal building is done in the form of the displacements and Storey shears for static and Response spectrum methods with eccentricity and without eccentricity. Table X shows the displacement in X-direction for Data Centre Building DCB-02.

TABLE X. DISPLACEMENT IN X DIRECTION FOR DATA CENTRE BUILDING DCB-02

Displacement: X direction				
	Static		*Response Spectrum*	
Storey	EQX-ey-0	EQX-ey-5%	RSX-ey-0	RSX ey-5%
6	15.901	20.12	6.442	6.848
5	14.391	18.238	5.895	6.257
4	12.03	15.27	5.027	5.327
3	8.903	11.321	3.815	4.035
2	5.167	6.577	2.272	2.401
1	1.443	1.833	0.655	0.693

Displacements in mm for X direction for Data centre building DCB-02 is shown in Fig.21.

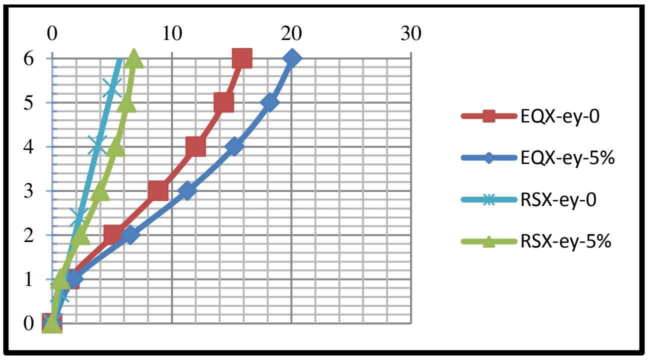

Figure 21. Displacements in mm for X direction static and response spectrum with and without eccentricity for data centre building DCB-02.

Table XI. shows the storey shear in X-direction for data centre building DCB-02

TABLE XI. STOREY SHEAR IN X DIRECTION FOR DATA BUILDING DCB-02

Storey Shear: X direction				
	Static		Response Spectrum	
Storey	EQX-ey-0	EQX-ey-5%	RSX-ey-0	RSX ey-5%
6	843.6	1147.2	296.9	296.9
5	1880.4	2557.4	639.7	639.7
4	2532.5	3444.2	873.6	873.6
3	2888.6	3928.5	1064.0	1064.0
2	3009.9	4093.5	1190.5	1190.5
1	3033.4	4125.4	1240.5	1240.5

Figure 22.shows the Storey shear in X-dir for static and response spectrum method for data centre building DCB-02.

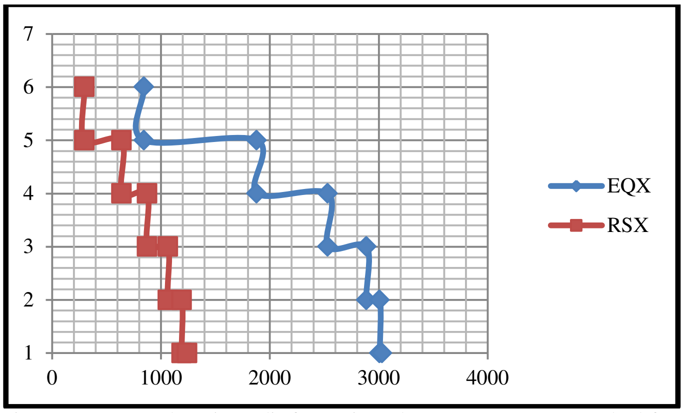

Figure 22. Storey shear in X-dir for static and response spectrum method for data centre building DCB-02.

Displacements in mm for Y-direction for data centre building DCB-02 with and without eccentricity are given in Table XII.

TABLE XII. DISPLACEMENT IN Y DIRECTION FOR DATA CENTRE BUILDING DCB-02

Displacement: Y direction				
Storey	***Static***		***Response Spectrum***	
	EQY-ex-0	***EQY ex-5%***	***RSY-ex-0***	***RSY ex-5%***
6	18.061	17.684	7.14	8.38
5	15.864	17.925	6.348	7.438
4	12.731	15.749	5.212	6.099
3	8.899	12.193	3.761	4.4
2	4.969	7.556	2.171	2.537
1	1.429	1.268	0.643	0.749
0	0	0	0	0

Displacements in mm for Y direction for Data centre building DCB-02 is shown in Fig.23.

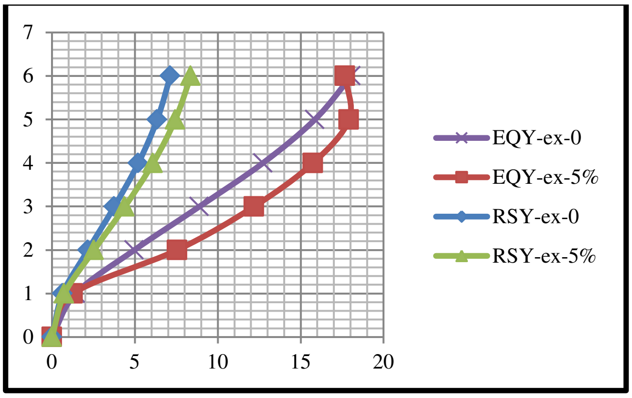

Figure 23. Displacements in mm for Y direction static and response spectrum with and without eccentricity for data centre building DCB-02.

Storey shear in Y-direction for data centre building DCB-02 is given in Table XIII.

TABLE XIII. STOREY SHEAR IN Y DIRECTION FOR DATA CENTRE DCB-02

Storey Shear: Y direction				
Storey	***Static***		***Response Spectrum***	
	EQY-ex-0	***EQY ex-5%***	***RSY-ex-0***	***RSY ex-5%***
6	869.1	1182.0	366.3	366.3
5	1937.5	2635.0	734.9	734.9
4	2609.3	3548.6	969.6	969.6
3	2976.2	4047.7	1163.1	1163.1
2	3101.2	4217.6	1308.1	1308.1
1	3125.3	4250.5	1375.6	1375.6

Storey shear in Y direction for Data centre building DCB-02 is shown in Fig.24.

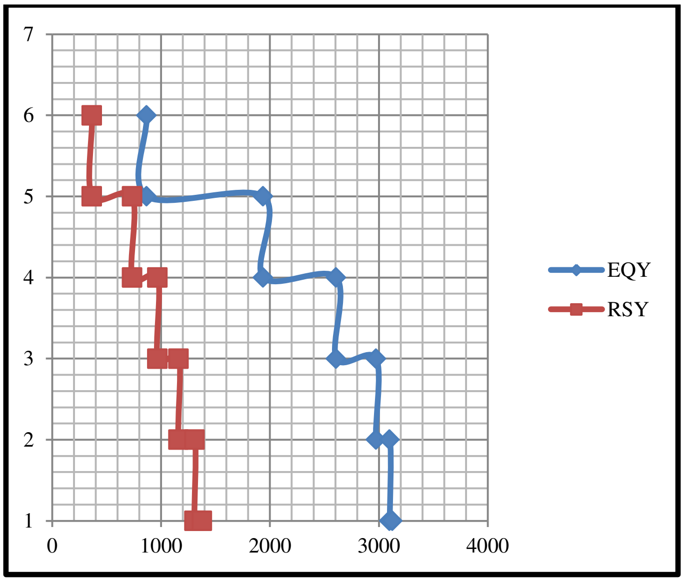

Figure 24. Storey shear in Y direction static and response spectrum for data centre building DCB-02.

VI. RESULTS: DCB-02(NORMAL LOADING)

A. Displacements, Storey Shear and Base Shear

For normal building DCB-02 displacements in mm is calculated for X and Y directions for static and response spectrum method for with and without eccentricity.

Displacements in X-direction for normal buildings with and without eccentricity are given in Table XIV.

TABLE XIV. DISPLACEMENT IN X DIRECTION FOR NORMAL BUILDING DCB-02

Displacement: X direction				
Storey	**Static**		**Response Spectrum**	
	EQX-ey-0	**EQX-ey-5%**	**RSX-ey-0**	**RSX ey-5%**
6	16.108	20.379	5.952	6.343
5	14.538	18.421	5.437	5.785
4	12.136	15.402	4.635	4.922
3	8.981	11.419	3.52	3.731
2	5.212	6.634	2.1	2.224
1	1.452	1.844	0.605	0.641

Displacements for X-direction for Normal building DCB-02 are shown in Fig.25.

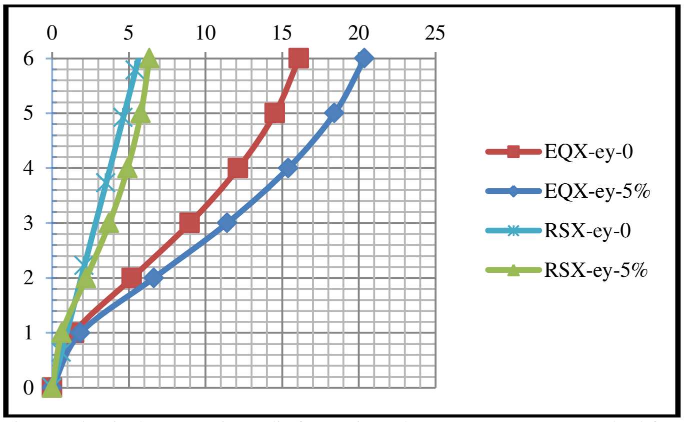

Figure 25. Displacement in X-dir for static and response spectrum method for normal building DCB-02.

Displacements in mm for Y-direction for normal building DCB-02 with and without eccentricity are given in Table XV.

TABLE XV. DISPLACEMENT IN Y DIRECTION FOR NORMAL BUILDING DCB-02

Displacement: Y direction				
Storey	***Static***		***Response Spectrum***	
	EQY-ex-0	***EQY ex-5%***	***RSY-ex-0***	***RSY ex-5%***
6	18.105	24.918	6.931	8.093
5	15.865	21.668	6.148	7.167
4	12.714	17.338	5.042	5.87
3	8.884	12.209	3.64	4.237
2	4.958	6.814	2.104	2.445
1	1.422	1.945	0.623	0.721
0	0	0	0	0

Displacements in mm for Y direction for normal building DCB-02 are shown in Fig.26.

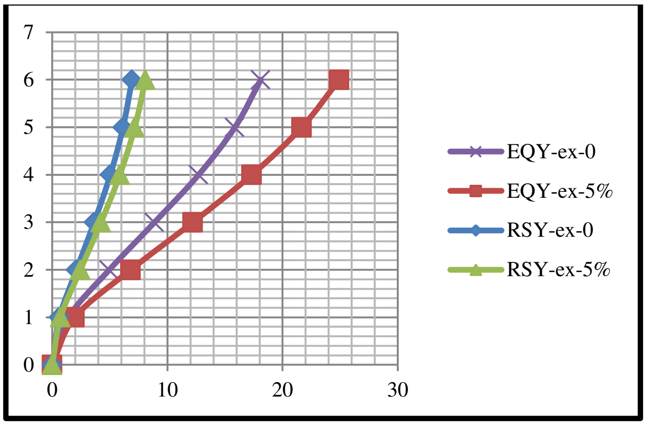

Figure 26. Displacements in mm for Y direction static and response spectrum with and without eccentricity for normal building DCB-02

Storey shear in X-direction for DCB-02 normal building is shown in Table XVI.

TABLE XVI. STOREY SHEAR IN X DIRECTION FOR DCB-02 NORMAL BUILDING

Storey Shear: X direction				
Storey	***Static***		***Response Spectrum***	
	EQX-ey-0	**EQX-ey-5%**	**RSX-ey-0**	**RSX ey-5%**
6	911.3	1239.4	301.7	301.7
5	1887.3	2566.7	606.2	606.2
4	2503.0	3404.0	816.9	816.9
3	2838.0	3859.6	988.3	988.3
2	2963.3	4030.0	1113.0	1113.0
1	2988.6	4064.5	1165.3	1165.3

Storey shear in X direction for DCB-02 Normal Building is shown in Fig.27.

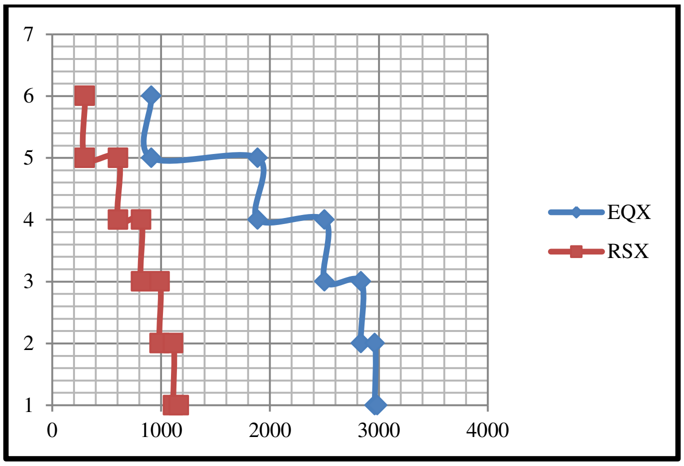

Figure 27. Storey shear in X direction static and response spectrum for DCB-02 Normal Building.

Storey shear in Y-direction for DCB-02 normal building is shown in Table XVII.

TABLE XVII. STOREY SHEAR IN Y DIRECTION FOR DCB-02 NORMAL BUILDING

Storey Shear: Y direction				
Storey	*Static*		*Response Spectrum*	
	EQY-ex-0	*EQY ex-5%*	*RSY-ex-0*	*RSY ex-5%*
6	911.3	1239.4	361.1	366.3
5	1887.3	2566.7	678.6	734.9
4	2503.0	3404.0	885.4	969.6
3	2838.0	3859.6	1055.7	1163.1
2	2963.3	4030.0	1195.4	1308.1
1	2988.6	4064.5	1265.4	1375.6

Storey shear in Y direction for DCB-02 Normal Building is shown in Fig.28.

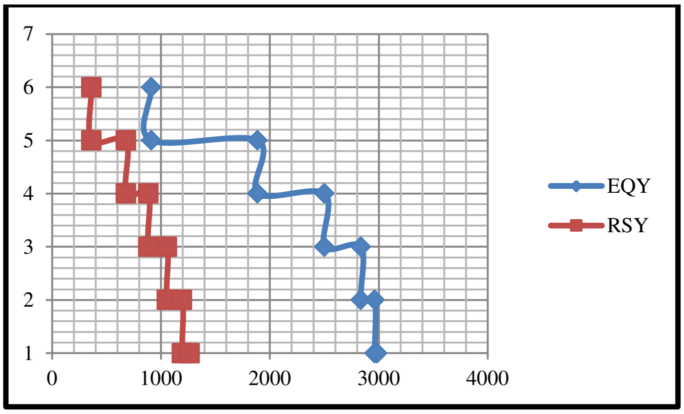

Figure 28. Storey shear in Y direction static and response spectrum for DCB-02 Normal Building.

VII. CONCLUSIONS

1) Eccentricity increases displacements values of Data centre buildings. Eccentricity should be considered whilst designing the sensitive buildings like data centre with heavy loads.

2) There is significant increase in Storey shear and Base shear for Data centre buildings with heavy loads compare to that of normal buildings of same configuration with normal loading.

3) Base shear are found to be more for Data centre buildings with heavy loading in both static and dynamic analysis compare to that of normal buildings of same configuration.

4) Data centre buildings have drop beams at the junction of the server area and other areas to accommodate the raised floor which are safe in deflection and strength.

5) The presence of heavy loading in server areas in data centre buildings influences the overall behavior of structures when subjected to lateral forces.

6) Data centre buildings are to be design properly to achieve the functional requirements of architectural and space along with technical requirements of heavy loads.

7) Optimal equipment space can be achieved in data centre buildings by effective structural planning by positioning and orienting the columns.

8) Coordinated Architectural and structural layout will have huge impact on number of racks in data centers.

9) Structural layout of Data centre building depends on factors such as architectural constraints, large column free areas to facilitate performance of HVAC systems, accommodation of optimum number of racks.

10) Data centre buildings being sensitive structures are to be given special attention for seismic design so as to have effective lateral force resisting system.

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