Static, Dynamic and Pogressive Collapse Analysis of Multi Storey (G+10) Residential Building by ETABS Software

PonnanaRamprasad, MadhusmitaMoharana, Ch. Chandra Mouli

Abstract: ***This project presents an attempt to do static, dynamic and progressive collapse analysis of multistory (G+10) residential building by ETABS (Extended 3D Analysis of Building Systems). ETABS is software that helps to anatomization and design of low and high-rise buildings and frame structures. In this project G+10 RC frame building is analysis statically (linear method) and dynamically (Response Spectrum method) along with Progressive Collapse analysis. All the members of the project are analyzed as per Indian codes IS 456:2000, IS 800:2007, and IS 1893:2002 (part1) code using this software. Here the result for Story stiffness, Base shear, Story Shear, Overturning moments, Maximum displacement, and Story Drift is compared between static and dynamic results for Zone2-(case1), Zone3-(case2), Zone4-(case3), Zone5-(case4) with medium soil type and for Progressive Collapse analysis***
GSA guidelines are followed.
As per GSA guidelines three column removal cases for each case1, case2, case3, and case4 individually studied, namely Corner column removal, Exterior column removal and interior column removal at ground floor. For all three cases linear analysis study has been undertaken and DCR ratios are evaluated. Member having DCR ratio greater than 2 will going to fail for corresponding column removal case.

Key Words: Static analysis, Dynamic analysis, Progressive collapse analysis, GSA Guidelines.

I. INTRODUCTION

For proper design of the building, the building should be check statically and dynamically under different load condition so; that the building is safe from different types of disaster which is likely to come after the construction of the building is over. Generally, we consider Self weight, dead loads, Live Loads, wind loads and Earthquake loads for Static and dynamic Analysis. However, after doing static and dynamic analysis also we not sure the structure is safe against local failure due to sudden loss of Column in the structure or abnormal loading like blast of cylinder or due to terrorist attack. So, we have move one step further and check our building against failure of Column at different location in ground floor as per General Service Administration (GSA) guidelines.

1.1 GUIDELINES OF GSA

1.1.1 Facility security levels (FSL):

The facility security level resolve to define the norms and process for determining the FSL of a federal facility, which categorizes facilities, depend on the analysis of several security-related facility factors, including its target attractiveness, as well as its value or criticality.

1.1.2 FSL I & II:

Specified the low occupancy and risk level correlated with these types of facilities, progressive collapse design is not preferred for FSL I and II, irrespective of the number of floors.

1.1.3 FSL III &IV:

These Guidelines are relevant to FSL III and IV buildings with four stories or more sustained from the lowest point of exterior grade to the highest point of elevation. Uninhabited floors such as mechanical penthouses or parking shall not be considered a story. It shall implement both the Alternate Path and Redundancy design procedures.

1.1.4 FSL V:

These Guidelines are used for all FSL V buildings regardless of number of floors. FSL V facilities shall implement the Alternate Path method for identification of vertical load resisting element removal area. Redundancy design procedures not required for FSL V facilities.

II. LITRATURE REVIEW

- Sana Fatema et.al (2016)[12] have publish a journal on "Progressive Collapse of Reinforced Concrete" as per GSA guidelines using ETABS software in International Journal of Emerging Trends in Science and Technology for evaluation of Progressive collapse linear static method and nonlinear static method of analysis has been used and they have concluded that shear in beam is not critical in any case, Columns are also not critical in Progressive collapse. But by Linear static analysis and nonlinear static it was observed that beams are going to fail in flexure.
- GirumMindaye et.al (2016)[9] have publish a journal on "Seismic Analysis of a Multistory RC Frame Building in Different Seismic Zones" in International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)which compares the story Stiffness, Base shear, Lateral force, Story Shear, Story displacement, Overturning moments and story drift statically and dynamically for different Zones cases.

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PonnanaRamprasad, M.Tech(Ph.D), Department of Civil engineering, Assistant Professor, Aditya Institute of Technology & Management, Tekkali, Amdhrapradesh.
MadhusmitaMoharana, M.Tech, Department of Civil engineering, Aditya Institute of Technology & Management, K.Kotturu, India.
CH. Chandra Mouli, M.Tech(Ph.D), Department of Civil engineering, Snr. Assistant Professor, Aditya Institute of Technology & Management, K.Kotturu, India.

- B. Srikanth et al (2013)[5] has published a journal on "Comparative Study of Seismic Response for Seismic Coefficient and Response Spectrum Methods" to analyze 20 storied building by both methods. In Response Spectrum Method, the time periods, natural frequencies and mode shape coefficients were calculated by MATLAB program then remaining process was done by manually. The modal combination rule for Response Spectrum Analysis was SRSS. The main parameters considered in that study was to compare the seismic performance of different Zones i.e. II and V were Base Shear, Story Moment and lateral forces.

III. METHODOLOGY

To understand the basic requirements such as safety, durability, economy, aesthetic appearance, feasibility, practicability and acceptability following methodology is followed.

3.1. Study of different Zones and Soil data collection:

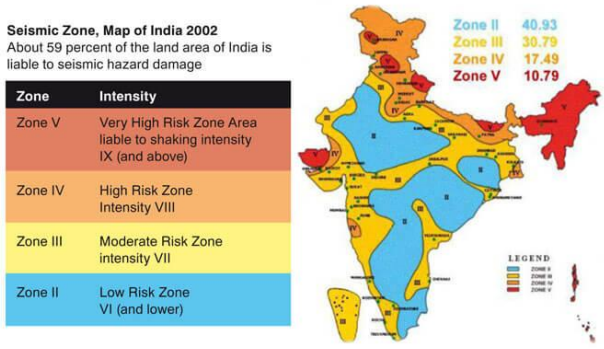


Fig 1.1 Seismic Zones of India

- For the analysis of the building, we have taken 4 cases in each Zone. The Soil bearing Capacity is assumed to be 200 KN/m^2 with wind Speed of 50 m/s along X direction (0^0 and 180^0) and along Y direction (90^0 and 270^0).

3.2. Modeling and Loading:

In ETABS first Modeling of multistory building which is to be analysis is done. In modeling material to be used to build the structure is defined. The input dates used for modeling are described below:

- Building type: G+10 Residential Building
- Plan area: 20(m)*20(m)
- Beam size: 300(mm)*300 (mm)
- Column size: 350(mm)*350 (mm)
- Beam clear cover to Longitudinal Rebar Group centroid: 35 mm
- Column clear cover to confinement Bars: 40 mm
- Slab thickness: 150mm
- Typical story height: 3m
- Bottom story height: 3m
- Live load, LL: 3kN/m² External Wall load: 10.4 KN/m
- Partition and floor finishing load, FL: 1.5kN/m^2
- Soil type: Type II (Medium Soil)
- Materials: M30 and Fe415 Grade
- Soil Bearing Capacity 200 KN/m^2
- For Static and dynamic Analysis: Earthquake Direction: X and Y Seismic is defined
  - Zone: II (Case 1) -Zone factor 0.10,
  - Zone: III (Case 2)-Zone factor 0.16,
  - Zone: IV (Case 3) -Zone factor 0.24 &
  - Zone: V (Case 4) -Zone factor 0.36
- For Progressive Collapse Analysis: In Each Cases further there are 3 Cases they are:
  i) Corner Column Removal.
  ii) Exterior Column Removal.
  iii) Interior Column Removal.
- First a Response Spectrum function is defined for above 4 different Zones with Function Damping Ratio as 0.05.

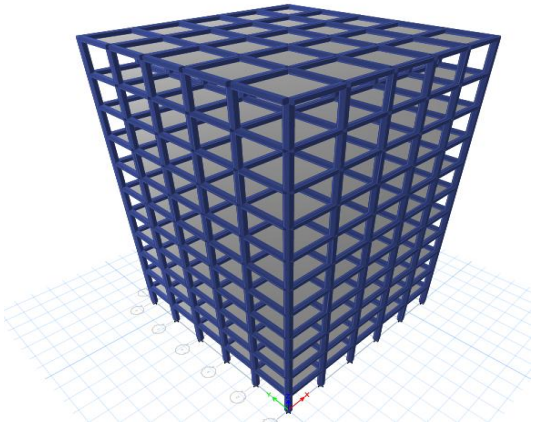


Fig 1.2 G+10 modeling using ETABS

3.3 Comparison of Static and Dynamic output:

After modeling and loading is done, the model is checked and design is done. The result for the for Story stiffness, Base shear, Story Shear, Overturning moments, Maximum displacement, and Story Drift is compared between static and dynamic results for Zone 2(case1), 3(case2),4(case3), 5(case4).

Static loads are varies steadily. But dynamic loads are changes with time quickly in comparison to the structure's natural frequency. Due to change of loading steadily or quickly , the response of the structures varies static or dynamic analysis.

3.4 For Linear Static PC Analysis:

PCA by Linear Static is accomplishing as per General Service Administration (GSA) guidelines. Columns are removed methodically.. Here 3 case of column removal (Corner column, Exterior column and Interior column) are studied. Due to column removal cases identification of critical sections is done then DCR values are estimated. Because of high shear capacity DCR ratio is not evaluation for Shear of beam and in no case DCR of shear of beam will exceed more than one. Load combination as per GSA GLD = 2 (1.2Dead Load + 0.5Live Load) for column removal region Combination and G = (1.2DL + 0.5LL) for other.

IV. RESULT AND DISCUSSIONS

The result evaluated for the Story Stiffness, Base Shear, Story Shear, Overturning Moment, Maximum Story displacement and Story Drift for Case1, Case2, Case3, Case4 are shown in respective Table and Graph and with discussions.

STORY STIFFNESS

Table: 1 Story Stiffness in X and Y direction

Story	Static X(KN/m)	Dynamic X(KN/m)	Static Y(KN/m)	Dynamic Y(KN/m)
1	294569.764	297471.346	295296.4	298234.91
2	196129.332	198186.872	196701.6	198757.71
3	187733.35	188977.494	188193.4	189520.81
4	185686.177	186720.833	186039.1	187145.82
5	184483.879	185330.067	184734.5	185635.35
6	183386.199	184234.671	183537.2	184431.39
7	182179.331	183589.656	182220.1	183687.55
8	180589.478	182872.451	180486.5	182863.11
9	177905.304	182294.676	177576.1	182129.65
10	170892.282	179021.728	170151.1	178553.51
11	130156.086	139853.902	128911.5	138914.3

Figure: 2.1Story Stiffness in X direction

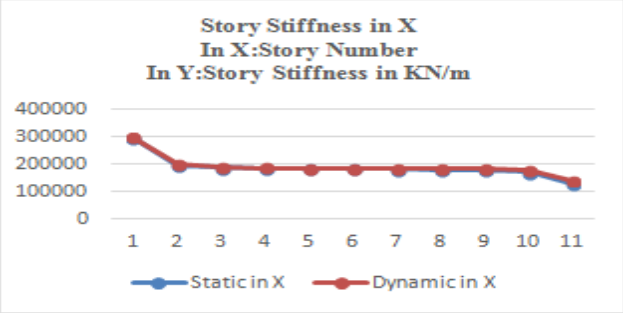
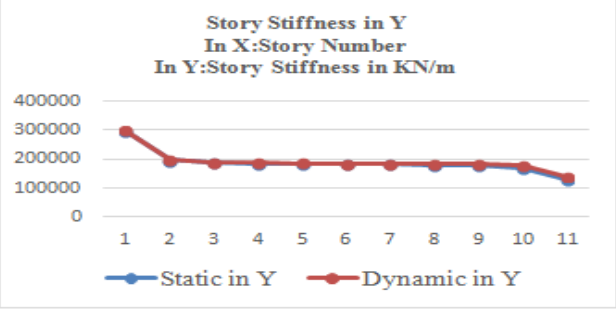


Figure: 2.2 Story Stiffness in Y direction



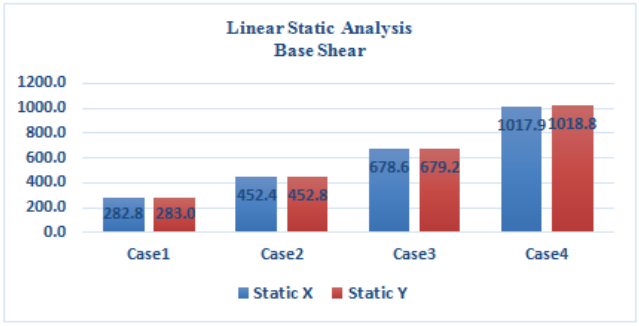
From figure 2.1 and 2.2, it was observed that there was increment in Shear Stiffness by 6.93% and 7.2% when compared Static Story Stiffness in X direction with respect to Static Stiffness in Y direction.

BASE SHEAR TABLE

Table: 2 Linear Static Analysis Base Shear and Response Spectrum Analysis Base Shear

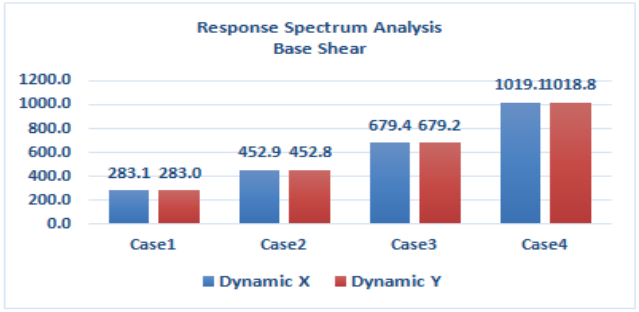
Linear Static Analysis Base Shear				Response Spectrum Analysis Base Shear		
Case	Static X(KN)	Static Y(KN)		Case	Dynamic X(KN)	Dynamic Y(KN)
Case1	282.8	283.0		Case1	283.1	283.0
Case2	452.4	452.8		Case2	452.9	452.8
Case3	678.6	679.2		Case3	679.4	679.2
Case4	1017.9	1018.8		Case4	1019.1	1018.8
Base Shear in the X-Direction				Base Shear in the Y-Direction		
Case	Static X(KN)	Dynamic X(KN)		Case	Static Y(KN)	Dynamic Y(KN)
Case1	282.8	283.1		Case1	283.0	283.0
Case2	452.4	452.9		Case2	452.8	452.8
Case3	678.6	679.4		Case3	679.2	679.2
Case4	1017.9	1019.1		Case4	1018.8	1018.8

Figure: 3.1 Linear Static AnalysisBase Shear



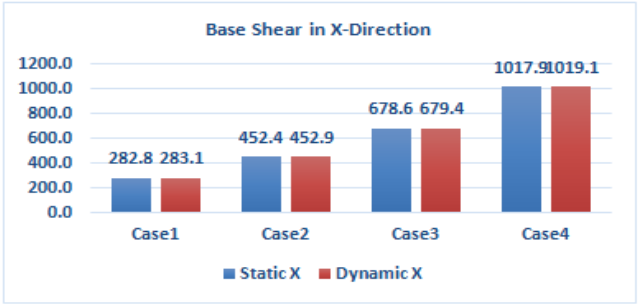
From figure 3.1, it was observed that there was increment in base shear by 0.07%,0.08% 0.08% and 0.08% when compared Static base shear in X direction with respect to Static base Shear in Y direction in Case 1, Case 2, Case3 and Case4 respectively.

Figure: 3.2 Response Spectrum Analysis of Base Shear



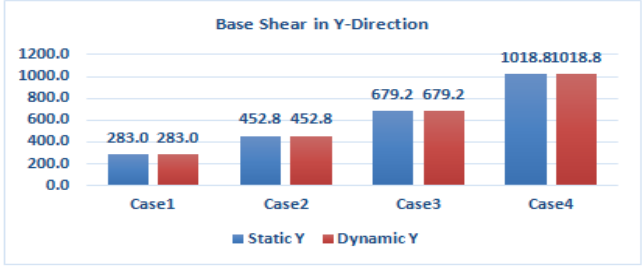
From figure 3.2, it was observed that there was increment in base shear by 0.03%, 0.02%, 0.03%, 0.03% when compared Dynamic base shear in X direction with respect to Dynamic base Shear in Y direction in Case1, Case 2 Case3 and Case4 respectively.

Figure: 3.3 Base Shear in X-direction



From figure 3.3, it was observed that there was increment in base shear by 0.11%when compared Dynamic base shear in X direction with respect to Dynamic base Shear in Y direction in Case1, Case2, Case3 and Case4 respectively.

Figure: 3.4 Base Shears in Y-Direction



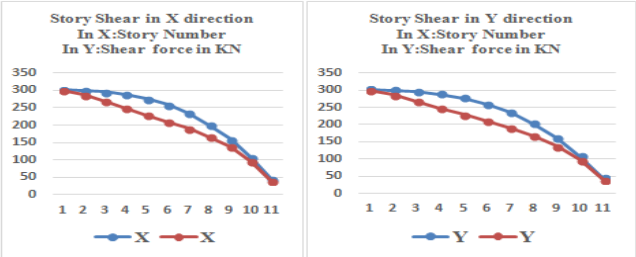
From figure 3.4, it was observed that there was no variation between Static Base shear and Dynamic Base Shear in Y direction.

STORY SHEAR

Table: 3.1 Case 1: Story Shear in X and Y Direction

Story shear	X-Direction		Y-Direction	
Story	Static(KN)	Dynamic(KN)	Static(KN)	Dynamic(KN)
1	301.7258	298.7295	301.9426	298.5918
2	299.7061	287.1535	299.9245	287.001
3	295.4686	267.788	295.6883	267.6174
4	287.9683	248.0715	288.1867	247.888
5	276.0293	228.7348	276.2424	228.5623
6	258.4391	209.7878	258.6419	209.6571
7	233.9733	190.2676	234.1594	190.1979
8	201.4033	166.7837	201.5654	166.7728
9	159.4996	137.071	159.6293	137.0936
10	107.033	96.2862	107.1207	96.3135
11	43.7201	39.6449	43.7563	39.6699

Figure 4.1Case 1: Story Shear in X and Y Direction

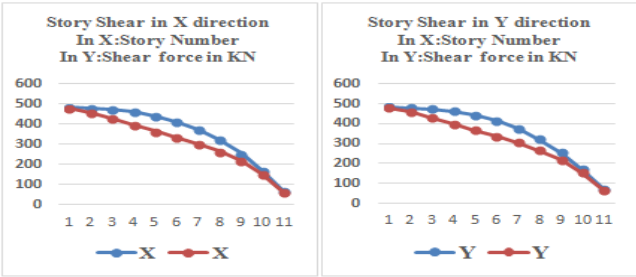


From figure 4.1, it was observed that there was a decrement in Story Shear by 23.19%,18.94% in X-direction and Y-direction respectively in 6th Story when compared to Static Story Shear with respect to Dynamic Story Shear in Case 1.

Table: 3.2 Case 2: Story Shear in X and Y Direction

Story shear	X-Direction		Y-Direction	
Story	Static(KN)	Dynamic(KN)	Static(KN)	Dynamic(KN)
1	482.7612	477.9671	483.1081	477.7469
2	479.5298	459.4456	479.8793	459.2016
3	472.7498	428.4608	473.1013	428.1879
4	460.7493	396.9144	461.0987	396.6208
5	441.6469	365.9757	441.9879	365.6997
6	413.5026	335.6604	413.827	335.4513
7	374.3573	304.4281	374.655	304.3166
8	322.2454	266.8539	322.5046	266.8365
9	255.1994	219.3136	255.4068	219.3498
10	171.2528	154.0579	171.3931	154.1016
11	69.9522	63.4319	70.01	63.4719

Figure 4.2Case 2: Story Shear in X and Y Direction

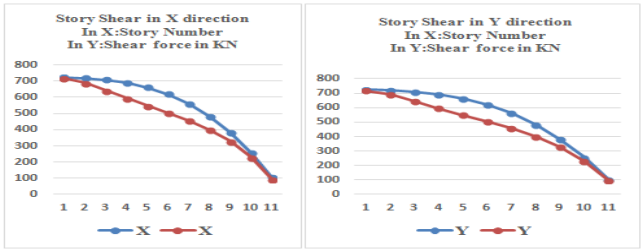


From figure 4.2, it was observed that there was a decrement in Story Shear by 23.19%,23.36% in X-direction and Y-direction respectively in 6th Story when compared to Static Story Shear with respect to Dynamic Story Shear in Case 2.

Table: 3.3 Case 3: Story Shear in X and Y Direction

Story shear	X-Direction		Y-Direction	
Story	Static(KN)	Dynamic(KN)	Static(KN)	Dynamic(KN)
1	724.142	716.951	724.662	716.6203
2	719.295	689.168	719.819	688.8023
3	709.125	642.691	709.652	642.2818
4	691.124	595.372	691.648	594.9312
5	662.47	548.964	662.982	548.5496
6	620.254	503.491	620.74	503.177
7	561.536	456.642	561.983	456.4749
8	483.368	400.281	483.757	400.2548
9	382.799	328.97	383.11	329.0247
10	256.879	231.087	257.09	231.1523
11	104.928	95.1478	105.015	95.2078

Figure 4.3 Case 3: Story Shear in X and Y Direction

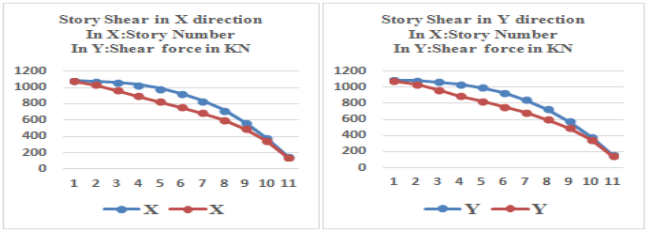


From figure 4.3, it was observed that there was a decrement in Story Shear by 23.19%,23.36 % in X-direction in Y-direction respectively in 6th Story when compared to Static Story Shear with respect to Dynamic Story Shear in Case 3.

Table: 3.4 Case 4: Story Shear in X and Y Direction

Story shear	X-Direction		Y-Direction	
Story	Static(KN)	Dynamic(KN)	Static(KN)	Dynamic(KN)
1	1086.213	1075.426	1086.993	1074.9305
2	1078.942	1033.753	1079.728	1033.2035
3	1063.687	964.0368	1064.478	963.4228
4	1036.686	893.0574	1037.472	892.3968
5	993.7055	823.4453	994.4727	822.8244
6	930.3809	755.2359	931.1107	754.7655
7	842.304	684.9633	842.9738	684.7123
8	725.0521	600.4212	725.6354	600.3822
9	574.1987	493.4556	574.6653	493.5371
10	385.3188	346.6302	385.6346	346.7285
11	157.3924	142.7218	157.5226	142.8117

Figure 4.4 Case 4: Story Shear in X and in Y Direction



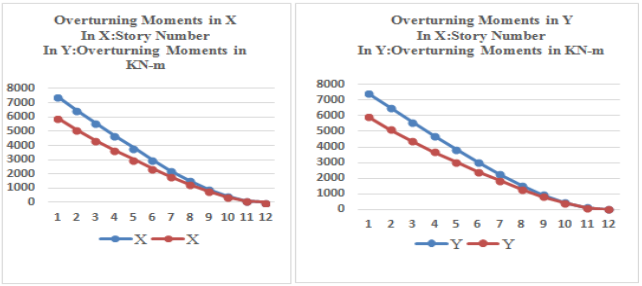
From figure 4.4, it was observed that there was a decrement in Story Shear by 23.19%, 23.36% in X-direction and Y-direction respectively in 6th Story when compared to Static Story Shear with respect to Dynamic Story Shear in Case 4.

OVERTURNING MOMENT

Table 4.1 Case 1: Overturning Moment in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(KNm)	Dynamic(KNm)	Static(KNm)	Dynamic(KNm)
base	7400.572	5899.346	7394.9	5903.793
1	6494.745	5111.335	6489.723	5115.004
2	5594.971	4367.904	5590.604	4370.709
3	4707.906	3671.903	4704.198	3673.811
4	3843.346	3018.801	3840.294	3019.874
5	3014.619	2404.705	3012.206	2405.106
6	2238.693	1827.864	2236.888	1827.83
7	1536.215	1292.9	1534.968	1292.675
8	931.5188	812.08	930.7582	811.8478
9	452.631	407.1155	452.2593	406.9588
10	131.2688	119.0097	131.1603	118.9348
11	0	0	0	0

Figure 5.1 Case 1: Overturning Moment in X and Y Direction

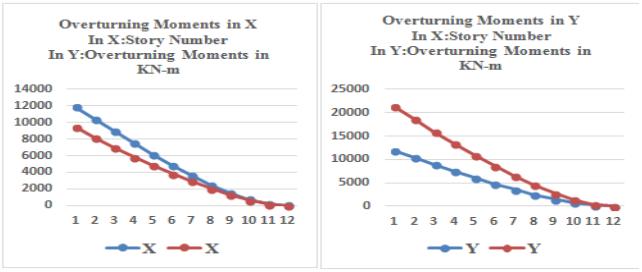


From figure 5.1, it was observed that there was a decrement in Story Overturning Moments by 28.21%, 28.05% in X-direction and Y-direction respectively in 3th Story when compared to Static Story Overturning Moments with respect to Dynamic Story Overturning Moments in Case1.

Table 4.2 Case 2: Overturning Moment in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(KNm)	Dynamic(KNm)	Static(KNm)	Dynamic(KNm)
base	11840.9	9438.95	11831.8	9446.07
1	10391.6	8178.14	10383.6	8184.01
2	8951.95	6988.65	8944.97	6993.13
3	7532.65	5875.04	7526.72	5878.1
4	6149.35	4830.08	6144.47	4831.8
5	4823.39	3847.53	4819.53	3848.17
6	3581.91	2924.58	3579.02	2924.53
7	2457.94	2068.64	2455.95	2068.28
8	1490.43	1299.33	1489.21	1298.96
9	724.21	651.385	723.615	651.134
10	210.03	190.416	209.857	190.296
11	0	0	0	0

Figure 5.2 Case 2: Overturning Moment in X and Y Direction

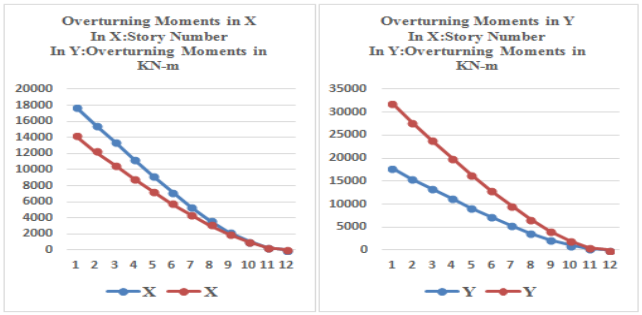


From figure 5.2, it was observed that there was a decrement in Story Overturning Moments by 28.21% in X-direction and increment by 28.05% Y-direction respectively in 3th Story when compared to Static Story Overturning Moments with respect to Dynamic Story Overturning Moments in Case2.

Table 4.3 Case 3: Overturning Moment in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(KNm)	Dynamic(KNm)	Static(KNm)	Dynamic(KNm)
base	17761.4	14158.4	17747.8	14169.1
1	15587.4	12267.2	15575.3	12276
2	13427.9	10483	13417.5	10489.7
3	11299	8812.57	11290.1	8817.15
4	9224.03	7245.12	9216.7	7247.7
5	7235.08	5771.29	7229.29	5772.26
6	5372.86	4386.87	5368.53	4386.79
7	3686.92	3102.96	3683.92	3102.42
8	2235.65	1948.99	2233.82	1948.43
9	1086.31	977.077	1085.42	976.701
10	315.045	285.623	314.785	285.444
11	0	0	0	0

Figure 5.3 Case 3: Overturning Moment in X and Y Direction

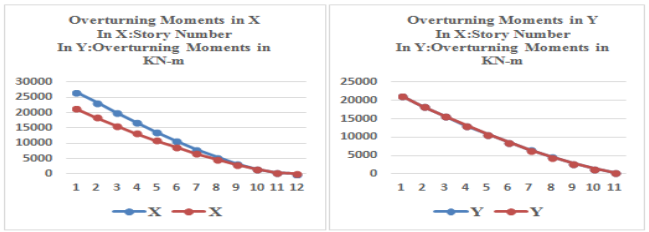


From figure 5.3, it was observed that there was a decrement in Story Overturning Moments by 28.2% in X-direction and increment by 28.05% Y-direction respectively in 3th Story when compared to Static Story Overturning Moments with respect to Dynamic Story Overturning Moments in Case3.

Table 4.4 Case 4: Overturning Moment in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(KNm)	Dynamic(KNm)	Static(KNm)	Dynamic(KNm)
base	26642.1	21237.6	21237.6	21253.7
1	23381.1	18400.8	18400.8	18414
2	20141.9	15724.5	15724.5	15734.6
3	16948.5	13218.8	13218.8	13225.7
4	13836	10867.7	10867.7	10871.5
5	10852.6	8656.94	8656.94	8658.38
6	8059.29	6580.31	6580.31	6580.19
7	5530.37	4654.44	4654.44	4653.63
8	3353.47	2923.49	2923.49	2922.65
9	1629.47	1465.62	1465.62	1465.05
10	472.568	428.435	428.435	428.165
11	0	0	0	0

Figure 5.4 Case 4: Overturning Moment in X and Y Direction



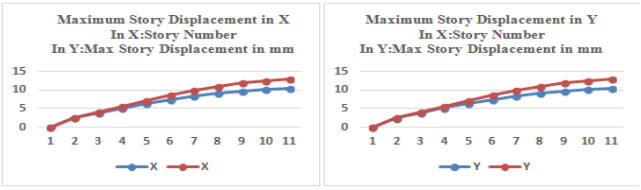
From figure 5.4, it was observed that there was a decrement in Story Overturning Moments by 28.21% in X-direction and increment by 0.075% Y-direction respectively in 3th Story when compared to Static Story Overturning Moments with respect to Dynamic Story Overturning Moments in Case3.

MAXIMUM STORY DISPLACEMENT

Table 5.1 Case 1: Maximum Story Displacement in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	0	0	0	0
2	2.486	2.558	2.497	2.553
3	3.911	4.137	3.93	4.129
4	5.221	5.693	5.249	5.684
5	6.403	7.195	6.44	7.185
6	7.453	8.61	7.498	8.6
7	8.366	9.9	8.419	9.89
8	9.131	11.019	9.192	11.011
9	9.729	11.92	9.798	11.914
10	10.139	12.549	10.214	12.546
11	10.356	12.888	10.438	12.889

Figure 6.1 Case 1: Maximum Story Displacement in X and Y Direction

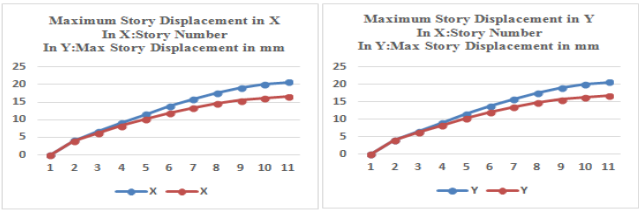


From figure 6.1, it was observed that there was an increment in Maximum Story Displacement by 24.45%, 23.48% in X-direction and Y-direction respectively in 11th Story when compared to Static Maximum Story Displacement with respect to Dynamic Maximum Story Displacement in Case1.

Table 5.2 Case 2: Maximum Story Displacement in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	0	0	0	0
2	4.093	3.977	4.085	3.996
3	6.619	6.257	6.607	6.289
4	9.109	8.353	9.094	8.398
5	11.513	10.245	11.496	10.303
6	13.776	11.925	13.76	11.997
7	15.839	13.386	15.824	13.471
8	17.631	14.609	17.618	14.708
9	19.071	15.567	19.062	15.677
10	20.078	16.222	20.074	16.343
11	20.62	16.57	20.622	16.7

Figure 6.2 Case 2: Maximum Story Displacement in X and Y Direction

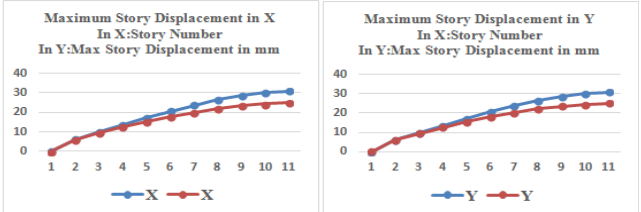


From figure 6.2, it was observed that there was a decrement in Maximum Story Displacement by 24.44%, 23.49% in X-direction and Y-direction respectively in 11th Story when compared to Static Maximum Story Displacement with respect to Dynamic Maximum Story Displacement in Case2.

Table 5.3 Case 3: Maximum Story Displacement in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	0	0	0	0
2	6.14	5.966	6.128	5.994
3	9.929	9.386	9.911	9.433
4	13.664	12.53	13.642	12.597
5	17.269	15.367	17.244	15.455
6	20.664	17.888	20.64	17.996
7	23.759	20.078	23.736	20.207
8	26.447	21.914	26.427	22.062
9	28.607	23.35	28.593	23.516
10	30.117	24.333	30.111	24.515
11	30.931	24.855	30.933	25.051

Figure 6.3 Case 3: Maximum Story Displacement in X and Y Direction

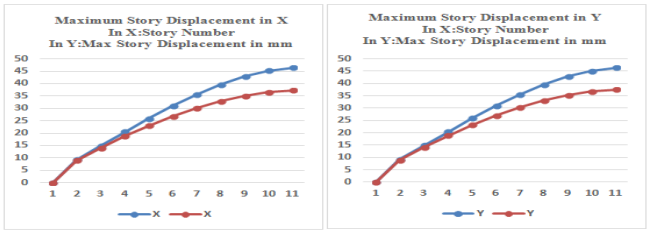


From figure 6.3, it was observed that there was a decrement in Maximum Story Displacement by 24.45%, 23.48% in X-direction and Y-direction respectively in 11th Story when compared to Static Maximum Story Displacement with respect to Dynamic Maximum Story Displacement in Case3.

Table 5.4 Case 4: Maximum Story Displacement in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	0	0	0	0
2	9.209	8.949	9.191	8.991
3	14.893	14.079	14.866	14.15
4	20.496	18.795	20.462	18.896
5	25.903	23.051	25.866	23.183
6	30.997	26.831	30.959	26.994
7	35.639	30.117	35.604	30.31
8	39.67	32.871	39.641	33.093
9	42.911	35.025	42.89	35.274
10	45.176	36.499	45.167	36.772
11	46.396	37.282	46.4	37.576

Figure 6.4 Case 4: Maximum Story Displacement in X and Y Direction



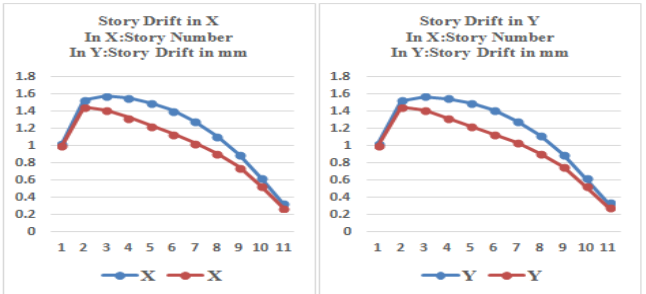
From figure 6.4, it was observed that there was a decrement in Maximum Story Displacement by 24.45%, 23.48% in X-direction and Y-direction respectively in 11th Story when compared to Static Maximum Story Displacement with respect to Dynamic Maximum Story Displacement in Case4.

STORY DRIFT

Table 6.1 Case 1: Story Drift in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	1.024	1.004	1.023	1.001
2	1.528	1.449	1.525	1.444
3	1.574	1.417	1.571	1.412
4	1.551	1.329	1.549	1.325
5	1.496	1.234	1.495	1.231
6	1.409	1.139	1.409	1.137
7	1.284	1.036	1.285	1.035
8	1.115	0.912	1.117	0.912
9	0.897	0.752	0.899	0.753
10	0.626	0.538	0.63	0.539
11	0.336	0.283	0.339	0.286

Figure 7.1 Case 1: Story Drift in X and Y Direction

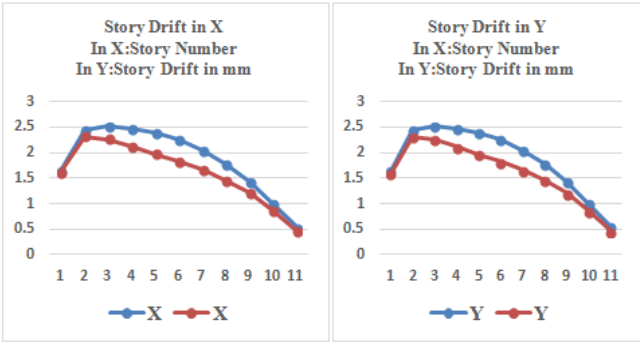


From figure 7.1, it was observed that there was a decrement in Story Drift by 19.65%, 19.02% in X-direction and Y-direction respectively in 7th Story when compared to Static Story Drift with respect to Dynamic Story Drift in Case1.

Table 6.2 Case 2: Story Drift in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	1.639	1.607	1.636	1.602
2	2.445	2.318	2.44	2.31
3	2.518	2.267	2.514	2.259
4	2.481	2.126	2.479	2.119
5	2.394	1.975	2.393	1.97
6	2.255	1.822	2.255	1.819
7	2.055	1.658	2.056	1.657
8	1.784	1.459	1.787	1.459
9	1.434	1.203	1.438	1.204
10	1.002	0.861	1.007	0.863
11	0.537	0.454	0.543	0.457

Fig 7.2 Case 2: Story Drift in X and Y Direction

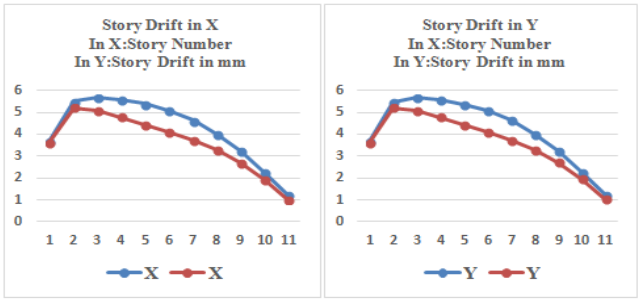


From figure 7.2, it was observed that there was a decrement in Story Drift by 23.95%, 24.08% in X-direction and Y-direction respectively in 7th Story when compared to Static Story Drift with respect to Dynamic Story Drift in Case2.

Table 6.3 Case 3: Story Drift in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	3.687	3.615	3.681	3.604
2	5.501	5.216	5.489	5.198
3	5.666	5.101	5.656	5.083
4	5.583	4.783	5.577	4.768
5	5.386	4.443	5.383	4.432
6	5.073	4.099	5.073	4.092
7	4.623	3.731	4.626	3.728
8	4.015	3.283	4.02	3.283
9	3.228	2.707	3.236	2.71
10	2.255	1.936	2.266	1.942
11	1.209	1.021	1.222	1.028

Figure 7.3 Case 3: Story Drift in X and Y Direction

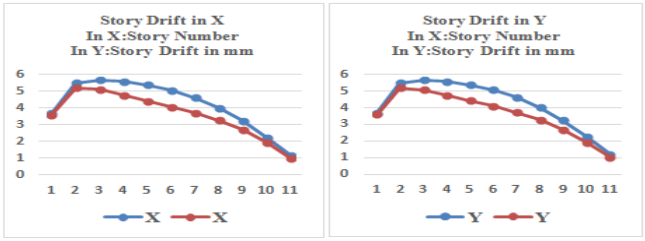


From figure 7.3, it was observed that there was a decrement in Story Drift by 23.91%, 24.09% in X-direction and Y-direction respectively in 7th Story when compared to Static Story Drift with respect to Dynamic Story Drift in Case3.

Table 6.4 Case 4: Story Drift in X and Y Direction

	X-Direction		Y-Direction	
Story	Static(mm)	Dynamic(mm)	Static(mm)	Dynamic(mm)
1	3.687	3.615	3.681	3.604
2	5.501	5.216	5.489	5.198
3	5.666	5.101	5.656	5.083
4	5.583	4.783	5.577	4.768
5	5.386	4.443	5.383	4.432
6	5.073	4.099	5.073	4.092
7	4.623	3.731	4.626	3.728
8	4.015	3.283	4.02	3.283
9	3.228	2.707	3.236	2.71
10	2.255	1.936	2.266	1.942
11	1.209	1.021	1.222	1.028

Figure 7.4 Case 4: Story Drift in X and Y Direction



From figure 7.4, it was observed that there was a decrement in Story Drift by 23.91%, 24.09% in X-direction and Y-direction respectively in 7th Story when compared to Static Story Drift with respect to Dynamic Story Drift in Case4.

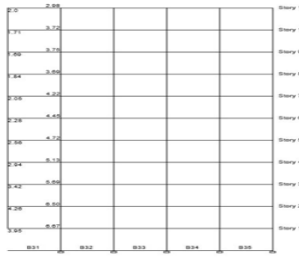


Figure 8.1 Case 1: Corner Column Removal

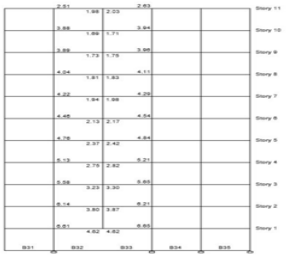


Figure 8.2 Case 1: Exterior Column Removal

From the figure 8.1 and 8.2, it was observed that there was continuous decrease in DCR value from bottom Story to top Story which concludes that the failure is more at bottom Story than top Story.

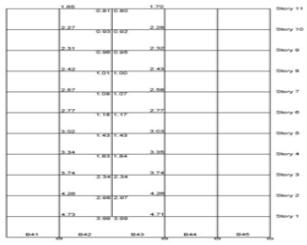


Figure 8.3 Case 1: Interior Column Removal

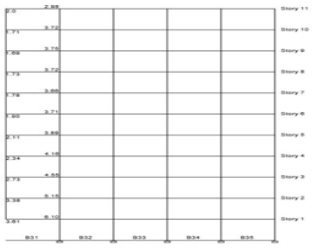


Figure 8.4 Case 2: Corner Column Removal

From the figure 8.3 and 8.4, it was observed that there was continuous decrease in DCR value from bottom Story to top Story which concludes that the failure is more at bottom Story than top Story and it was also found that in figure 8.3, the 11th Story beam was safe against Progressive Collapse.

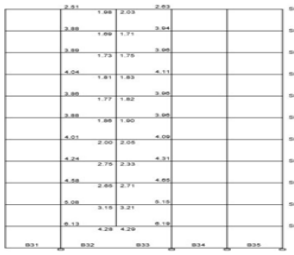


Figure 8.5 Case 2: Exterior Column Removal

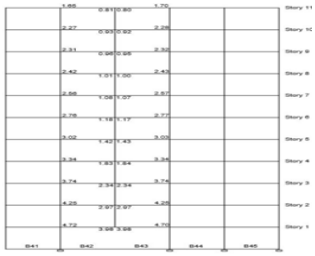


Figure 8.6 Case 2: Interior Column Removal

From the figure 8.5 and 8.6, it was observed that there was continuous decrease in DCR value from bottom Story to top Story which concludes that the failure is more at bottom Story than top Story and it was also found that in figure 8.6, the 11th Story beam was safe against Progressive Collapse.

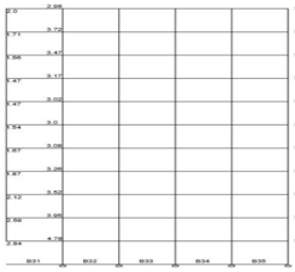


Figure 8.7 Case 3: Corner Column Removal

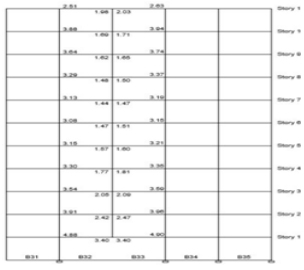


Figure 8.8 Case 3: Exterior Column Removal

From the figure 8.7 and 8.8, it was observed that there was continuous decrease in DCR value from bottom Story to top Story which concludes that the failure is more at bottom Story than top Story.

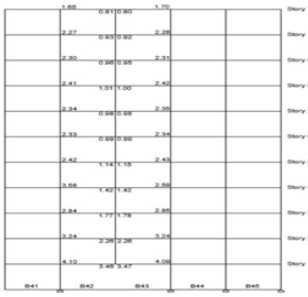


Figure 8.9 Case 3: Interior Column Removal

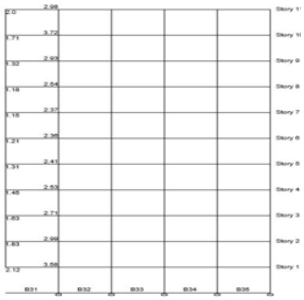


Figure 8.10 Case 4: Corner Column Remova

From the figure 8.9 and 8.10, it was observed that there was continuous decrease in DCR value from bottom Story to top Story which concludes that the failure is more at bottom Story than top Story and it was also found that in figure 8.9, the 11th Story beam was safe against Progressive Collapse.

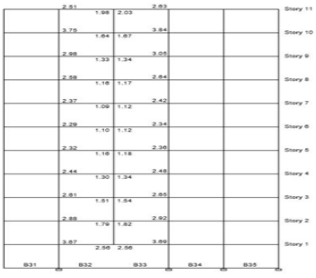


Figure 8.11 Case 4: Exterior Column Removal

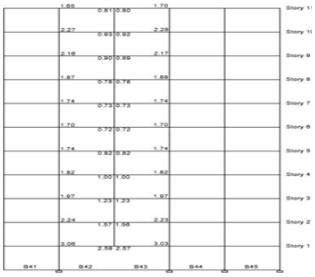


Figure 8.12 Case 4: Interior Column Removal

From the figure 8.11 and 8.12, it was observed that there was continuous decrease in DCR value from bottom Story to top Story which concludes that the failure is more at bottom Story than top Story and it was also found that in figure 8.12, the 3rd, 4th, 5th, 6th, 7th, 8th, 11th Story beam was safe against Progressive Collapse.

V. CONCLUSION

After doing Static, Dynamic and progressive Analysis following conclusion were made:

For Static and Dynamic Result:

- There is an increment in Story Stiffness by 6.93%, 7.2% in X and Y-direction respectively when compared to Static Story Stiffness with respect to its Dynamic Story Stiffness.
- The maximum variation in Linear Base Shear is by 0.08% and in Dynamic Base Shear is by0.03%
- There is a decrement in Story Shear by 23.19%, 23.36% in X-direction and Y-direction respectively when compared to Static Story Shear with respect to its Dynamic Story Shear.
- The maximum variation of Story Overturning Moments is by 28.21%, 28.05% in X-direction and Y-direction respectively when compared to Static Story Overturning Moments with respect to its Dynamic Story Overturning Moments.
- The maximum variation of Maximum Story Displacement is by 24.45%, 24.49% in X-direction and Y-direction respectively when compared to Static Maximum Story Displacement with respect to its Dynamic Maximum Story Displacement.
- There is a decrement in Story Drift by 23.95%, 24.09% in X-direction and Y-direction respectively when compared to Static Story Drift with respect to its Dynamic Story Drift.

For Progressive Collapse Result:

- It was observed that there is continuous decrease in DCR value from bottom Story to top Story, which conclude that the failure is more at bottom Story than top Story and it was also found that in Case 1,Case 2 and Case 3 for Interior Column Removal Case, beam in the 11Th Story is safe against PC.
- It was also observed that in Case 4 of Interior Column Removal Case, beam in 3rd ,4th,5th,6th ,7th ,8th and 11th Story were safe against Progressive Collapse.
- The Special Moment Resistance Frame (SMRF) by IS 456:2000 does not provide resistance to progressive Collapse. The SMRF frames are designed for lateral loads and PC failure on these frames due to gravity load.

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AUTHORS PROFILE

PONNANA RAMPRASAD, M.Tech(Ph.D), Department of Civil engineering, Assistant Professor, Aditya Institute of Technology & Management, K.Kotturu, India.

MADHUSMITA MOHARANA, M.Tech, Department of Civil engineering, Aditya Institute of Technology & Management, K.Kotturu, India.

CH. CHANDRA MOULI, M.Tech(Ph.D), Department of Civil engineering, Snr. Assistant Professor, Aditya Institute of Technology & Management, K.Kotturu, India.