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Comparative Study of Ten Storey Building with Blast and Seismic Loading

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Abstract - *In these days population is growing at an alarming rate. The cities and towns are growing faster at the same time. Thus, the multi-storeyed buildings are becoming more popular. Due to increase in terrorist activities resulting in impact of blast load on the structure is a serious issue and it may lead to failure of the structure, collapse and loss of life. An earthquake is a result of sudden release of energy in the earth crust that creates seismic waves. Seismic load is very powerful and it will collapse the structure in fraction of seconds this leads to loss of life and property. In the present study, ten storey RCC building is subjected 100, 500 and 1000kg charge weight of blast load with a standoff distance 30m, 40 and 50m. The blast parameters are determined by IS: 4991-1968.Same building is compared with seismic load in zone V. Analysis is carried out by using ETABS 2016. The response of the structure i,e storey displacement, storey drift, storey shear, column axial load, column bending moment are compared with building with blast and seismic loading for bare frame and building with shear wall in the corner. The number of failed members in the case of charge weight of 1000kg of charge weight is more when compared in the case of charge weight of 100kg. And also more number of failure member occurs in the blast case than earthquake.*

Key Words: Blast load, Standoff distance, charge weight, E tabs 2016, Tributary area.

1. INTRODUCTION

In these days population is growing at an alarming rate. The cities and towns are growing faster at the same time.. Thus, the multi-storeyed buildings are becoming more popular. For construction of any structure, safety economy and accuracy are three important criterion that an engineer must consider. The effect of lateral loads like earthquake force, wind force and blast force etc., are attain increasing significance and almost every designer is faced with the problem of providing sufficient strength and stability next to lateral loads. The study of effect of blast load on the structure has been an area of technical investigation in last few years. Due to increase in terrorist activities resulting in impact of blast load on the structure is a serious issue and it may leads to failure of the structure, collapse and loss of life. A bomb explosion can cause catastrophic damage on the buildings external and internal frames depending on the occurrence of the blast (within or immediately nearby buildings). Generally, the structures are not designed to withstand the blast load because the intensity of load is very high when compared with the other loads and cost of construction is high. Therefore, these structures are subjected to damage due to blast.

1.1 Blast Waves and Explosion.

An explosion is a chemical reaction and quick release of stored energy consists of bright flash and a loud noise, it takes place within a few seconds which results in very high release of temperature and pressure. Blast wave is an area of pressure escalating supersonically outward from the centre of explosive as shown in Fig.1.1. It consists of leading shock front of compressed gases and it is followed by blast wind of negative pressure, which draws items back towards the centre. The shock waves generated due to blast is very harmful when the building is very close centre or at the location of constructive boundary. The blast wave consists of energy released during blast and the speed (velocity) of these waves is greater than the velocity of sound.

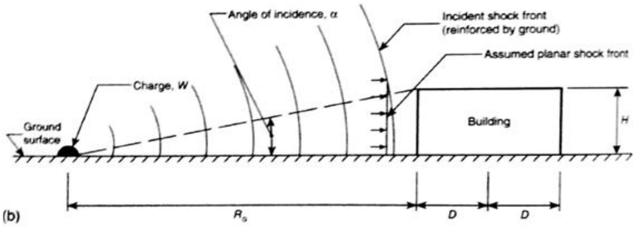

Fig -1.1: Blast wave or shock wave proportion

1.2 Type of explosives

An explosive is a chemical reaction occurs due to sudden release of hot gases. The main source for explosion is nuclear bombs or explosives. The explosives that are made up of cheap ingredients such as TNT or nitro-glycerine mixed with low-cost nitrates safety, hence the safety, reliability and performance of these explosives is difficult to assess. Military explosives are made up of expensive materials like TNT and RDX or HMX. Terrorists manufacture the explosives using Semtex in order to damage the buildings or other structure. The blast may occurred inside or outside of the structure. The impact of blast load produced due to blast on the building undergoes

Stationary randomness and transient or dynamic nature. Depending on the intensity of load, bombs and explosives are categorized as presented in Table- 1

Table -1: Type of explosives

Type of Explosive	Magnitude of explosion load
Small	Up to 5kg of TNT
Medium	Up to 20kg of TNT
Large	Up to 100kg of TNT
Very large	Up to 2500kg of TNT

1.3 Earthquake phenomenan

An earthquake is a result of sudden release of energy in the earth crust that creates seismic waves. Seismic load is very powerful and it will collapse the structure in fraction of seconds this leads to loss of life and property. The seismicity or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, earthquake. Lateral loads can develop high stresses, produce sway movement or cause vibration. The earthquakes are measured by using seismometers. In addition to IS: 456-2000, IS: 1893-2002 also referred while designing this type of structures.

2. METHODOLOGY

In the current study ten storey RCC building subjected to surface blast of 100,500 and 1000kg charge weight of explosive having a plan dimension of 30m X 30m as shown in figure with storey height as 3m.and remaining all storey heights as 3m with the standoff distance from the front face of the building using ETABS 2016. The blast load parameters are computed as per IS: 4991-1968 and the blast load is multiplied with its tributary area and these pressures are applied as a joint load on the front face of the building i.e. in the direction of 'x'. And the Same building is compared with seismic load in zone *V*. The response of the structure i,e storey displacement, storey drift, storey shear, column axial load, column bending moment are compared with building with blast and seismic loading for bare frame and building with shear wall in the corner.

2.1 Description of model

Plan: 30mX30m Number of Storeys: G+9 Height of storey: 3m

2.2 Properties of materials Grade of concrete: M25

Grade of rebar: Fe500 Density of concrete: 25 kN/m3 Density of steel: 78.5kN/m3 Poisson's Ratio: 0.2

2.3 Sectional Properties

Column: 500mm X 500mm Beam: 500mm X 500mm Slab: 200mm

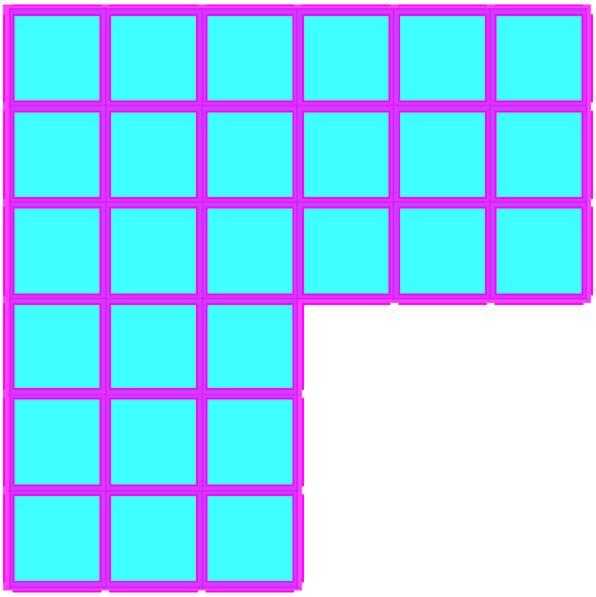

Fig -2.1: Plan of the model showing beans, column and slab.

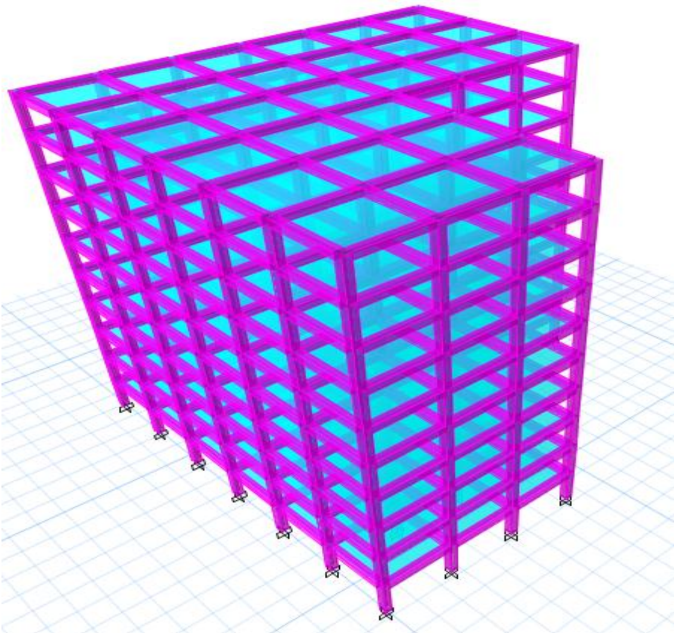

Fig -2.2: 3D view of the model

Table-2: Pressure and the joint load acting on the front face of the building acting at 30m at a charge weight of explosive 100kg.

Joint	Slab	X2	Y2	Z2	Distance b/w source and target in m	Scaled distance	P in kN/m2	t in milli sec	Area in m2	F in kN
1	STOREY1	30	3	0	30.15	65.0	79.786	13.194	15.0	1197
2		30	3	5	30.56	65.8	77.420	13.326	15.0	1161
3		30	3	10	31.76	68.4	72.941	13.534	15.0	1094
4		30	3	15	33.67	72.6	66.083	13.936	7.5	496
1	STOREY2	30	6	0	30.59	65.9	77.232	13.336	15.0	1158
2		30	6	5	31.00	66.8	75.688	13.409	15.0	1135
3		30	6	10	32.19	69.3	71.426	13.610	15.0	1071
4		30	6	15	34.07	73.4	64.652	14.048	7.5	485
1	STOREY3	30	9	0	31.32	67.5	74.535	13.461	15.0	1118
2		30	9	5	31.72	68.3	73.111	13.526	15.0	1097
3		30	9	10	32.88	70.8	68.942	13.753	15.0	1034
4		30	9	15	34.73	74.8	62.303	14.231	7.5	467
1	STOREY4	30	12	0	32.31	69.6	70.980	13.635	15.0	1065
2		30	12	5	32.70	70.4	69.599	13.715	15.0	1044
3		30	12	10	33.82	72.9	65.551	13.977	15.0	983
4		30	12	15	35.62	76.7	59.670	14.563	7.5	448
1	STOREY5	30	15	0	33.54	72.3	66.563	13.898	15.0	998
2		30	15	5	33.91	73.1	65.233	14.002	15.0	978
3		30	15	10	35.00	75.4	61.460	14.326	15.0	922
4		30	15	15	36.74	79.2	56.841	14.796	7.5	426
1	STOREY6	30	18	0	34.99	75.4	61.501	14.320	15.0	923
2		30	18	5	35.34	76.1	60.480	14.455	15.0	907
3		30	18	10	36.39	78.4	57.607	14.788	15.0	864
4		30	18	15	38.07	82.0	54.327	14.828	7.5	407
1	STOREY7	30	21	0	36.62	78.9	57.105	14.793	15.0	857
2		30	21	5	36.96	79.6	56.373	14.801	15.0	846
3		30	21	10	37.96	81.8	54.478	14.826	15.0	817
4		30	21	15	39.57	85.3	51.743	14.904	7.5	388
1	STOREY8	30	24	0	38.42	82.8	53.820	14.838	15.0	807
2		30	24	5	38.74	83.5	53.354	14.847	15.0	800
3		30	24	10	39.70	85.5	51.471	14.915	15.0	772
4		30	24	15	41.24	88.9	48.144	15.298	7.5	361
1	STOREY9	30	27	0	40.36	87.0	50.045	14.972	15.0	751
2		30	27	5	40.67	87.6	49.380	15.082	15.0	741
3		30	27	10	41.58	89.6	47.416	15.426	15.0	711
4		30	27	15	43.06	92.8	43.312	16.059	7.5	325
1	STOREY10	30	30	0	42.43	91.4	45.127	15.783	15.0	677
2		30	30	5	42.72	92.0	44.283	15.911	15.0	664
3		30	30	10	43.59	93.9	42.394	16.201	15.0	636
4		30	30	15	45.00	96.9	40.683	16.542	7.5	305

Table-3: Pressure and the joint load acting on the front face of the building acting at 30m at a charge weight of explosive 500kg.

Joint	Slab	X2	Y2	Z2	Distance b/w source and target in m	Scaled distance	P in kN/m2	t in milli sec	A in m2	F in kN
1	STOREY1	30	3	0	30.15	38.0	243.884	14.901	15.0	3658
2		30	3	5	30.56	38.5	235.755	15.074	15.0	3536
3		30	3	10	31.76	40.0	217.449	15.509	15.0	3262
4		30	3	15	33.67	42.4	192.580	16.191	7.5	1444
1	STOREY2	30	6	0	30.59	38.5	235.110	15.088	15.0	3527
2		30	6	5	31.00	39.1	227.405	15.254	15.0	3411
3		30	6	10	32.19	40.6	211.952	15.650	15.0	3179
4		30	6	15	34.07	42.9	187.391	16.377	7.5	1405
1	STOREY3	30	9	0	31.32	39.5	223.227	15.361	15.0	3348
2		30	9	5	31.72	40.0	218.064	15.493	15.0	3271
3		30	9	10	32.88	41.4	202.948	15.880	15.0	3044
4		30	9	15	34.73	43.8	178.876	16.682	7.5	1342
1	STOREY4	30	12	0	32.31	40.7	210.337	15.691	15.0	3155
2		30	12	5	32.70	41.2	205.330	15.819	15.0	3080
3		30	12	10	33.82	42.6	190.651	16.260	15.0	2860
4		30	12	15	35.62	44.9	167.217	17.100	7.5	1254
1	STOREY5	30	15	0	33.54	42.3	194.323	16.129	15.0	2915
2		30	15	5	33.91	42.7	189.498	16.302	15.0	2842
3		30	15	10	35.00	44.1	175.329	16.810	15.0	2630
4		30	15	15	36.74	46.3	157.384	17.520	7.5	1180
1	STOREY6	30	18	0	34.99	44.1	175.515	16.803	15.0	2633
2		30	18	5	35.34	44.5	170.886	16.969	15.0	2563
3		30	18	10	36.39	45.8	160.370	17.390	15.0	2406
4		30	18	15	38.07	48.0	146.268	18.005	7.5	1097
1	STOREY7	30	21	0	36.62	46.1	158.414	17.475	15.0	2376
2		30	21	5	36.96	46.6	155.560	17.600	15.0	2333
3		30	21	10	37.96	47.8	147.152	17.967	15.0	2207
4		30	21	15	39.57	49.9	134.849	18.509	7.5	1011
1	STOREY8	30	24	0	38.42	48.4	143.572	18.124	15.0	2154
2		30	24	5	38.74	48.8	141.123	18.232	15.0	2117
3		30	24	10	39.70	50.0	133.895	18.551	15.0	2008
4		30	24	15	41.24	52.0	123.505	19.066	7.5	926
1	STOREY9	30	27	0	40.36	50.9	128.891	18.771	15.0	1933
2		30	27	5	40.67	51.2	126.879	18.874	15.0	1903
3		30	27	10	41.58	52.4	121.518	19.178	15.0	1823
4		30	27	15	43.06	54.2	112.918	19.717	7.5	847
1	STOREY10	30	30	0	42.43	53.5	116.548	19.460	15.0	1748
2		30	30	5	42.72	53.8	114.822	19.558	15.0	1722
3		30	30	10	43.59	54.9	110.019	20.018	15.0	1650
4		30	30	15	45.00	56.7	102.315	20.817	7.5	767

Table- 4: Pressure and the joint load acting on the front face of the building acting at 30m at a charge weight of explosive 1000kg

Joint	Slab	X2	Y2	Z2	Distance b/w source and target in m	Scaled distance	P in kN/m2	t in milli sec	A in m2	F in kN
1	STOREY1	30	3	0	30.15	30.1	416.259	15.436	15.0	6244
2		30	3	5	30.56	30.6	405.965	15.562	15.0	6089
3		30	3	10	31.76	31.8	375.881	15.931	15.0	5638
4		30	3	15	33.67	33.7	329.252	16.677	7.5	2469
1	STOREY2	30	6	0	30.59	30.6	405.147	15.572	15.0	6077
2		30	6	5	31.00	31.0	395.000	15.697	15.0	5925
3		30	6	10	32.19	32.2	365.326	16.061	15.0	5480
4		30	6	15	34.07	34.1	319.953	16.893	7.5	2400
1	STOREY3	30	9	0	31.32	31.3	386.977	15.795	15.0	5805
2		30	9	5	31.72	31.7	377.062	15.917	15.0	5656
3		30	9	10	32.88	32.9	348.036	16.273	15.0	5221
4		30	9	15	34.73	34.7	304.691	17.249	7.5	2285
1	STOREY4	30	12	0	32.31	32.3	362.225	16.099	15.0	5433
2		30	12	5	32.70	32.7	352.611	16.217	15.0	5289
3		30	12	10	33.82	33.8	325.795	16.757	15.0	4887
4		30	12	15	35.62	35.6	283.796	17.735	7.5	2128
1	STOREY5	30	15	0	33.54	33.5	332.376	16.604	15.0	4986
2		30	15	5	33.91	33.9	323.728	16.805	15.0	4856
3		30	15	10	35.00	35.0	298.333	17.397	15.0	4475
4		30	15	15	36.74	36.7	263.370	18.252	7.5	1975
1	STOREY6	30	18	0	34.99	35.0	298.667	17.389	15.0	4480
2		30	18	5	35.34	35.3	290.372	17.582	15.0	4356
3		30	18	10	36.39	36.4	268.940	18.102	15.0	4034
4		30	18	15	38.07	38.1	242.637	18.808	7.5	1820
1	STOREY7	30	21	0	36.62	36.6	265.292	18.200	15.0	3979
2		30	21	5	36.96	37.0	259.969	18.343	15.0	3900
3		30	21	10	37.96	38.0	244.285	18.763	15.0	3664
4		30	21	15	39.57	39.6	222.082	19.391	7.5	1666
1	STOREY8	30	24	0	38.42	38.4	237.106	18.956	15.0	3557
2		30	24	5	38.74	38.7	232.030	19.092	15.0	3480
3		30	24	10	39.70	39.7	220.778	19.433	15.0	3312
4		30	24	15	41.24	41.2	204.820	19.948	7.5	1536
1	STOREY9	30	27	0	40.36	40.4	213.938	19.654	15.0	3209
2		30	27	5	40.67	40.7	210.750	19.756	15.0	3161
3		30	27	10	41.58	41.6	201.327	20.060	15.0	3020
4		30	27	15	43.06	43.1	186.066	20.694	7.5	1395
1	STOREY10	30	30	0	42.43	42.4	192.594	20.399	15.0	2889
2		30	30	5	42.72	42.7	189.560	20.536	15.0	2843
3		30	30	10	43.59	43.6	180.580	20.942	15.0	2709
4		30	30	15	45.00	45.0	166.000	21.600	7.5	1245

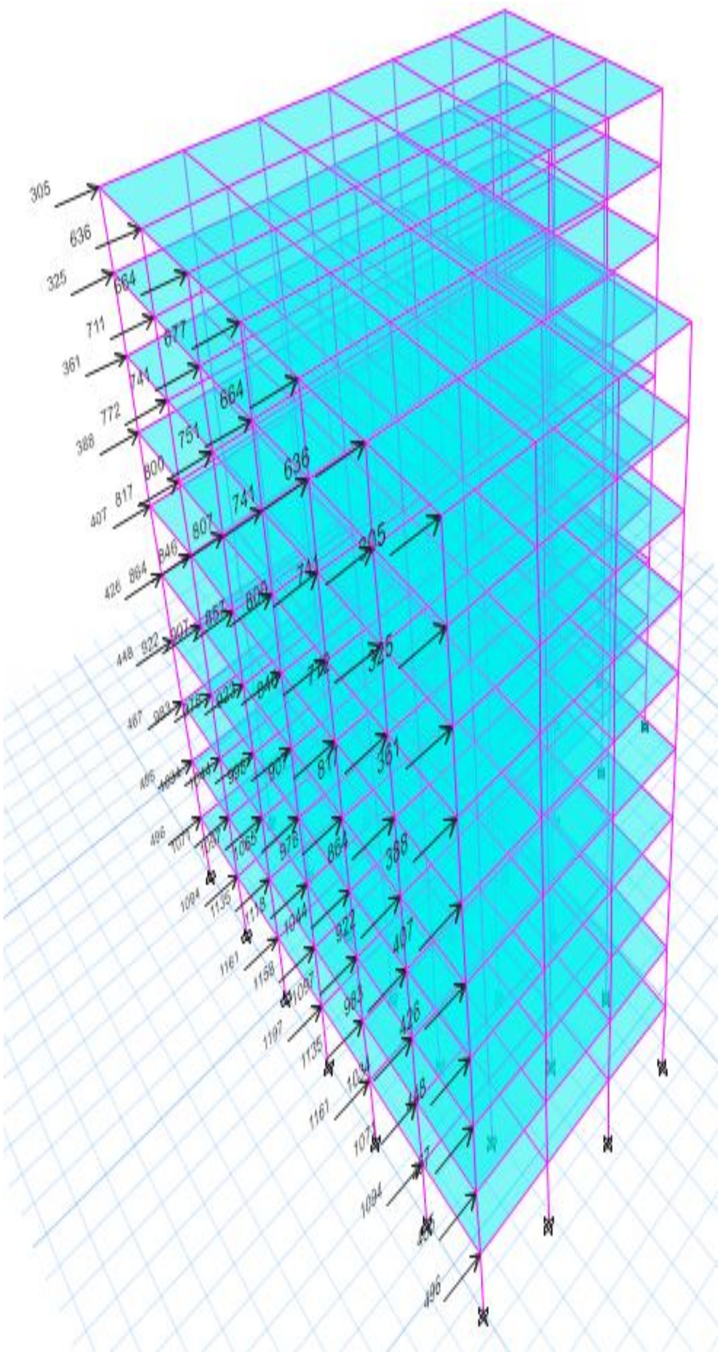

Fig 2.3 Blast Load applied as joint load when the 100kg blast located at a standoff distance of 30m.

3. RESULTS AND DISCUSSIONS

3.1 Storey displacement

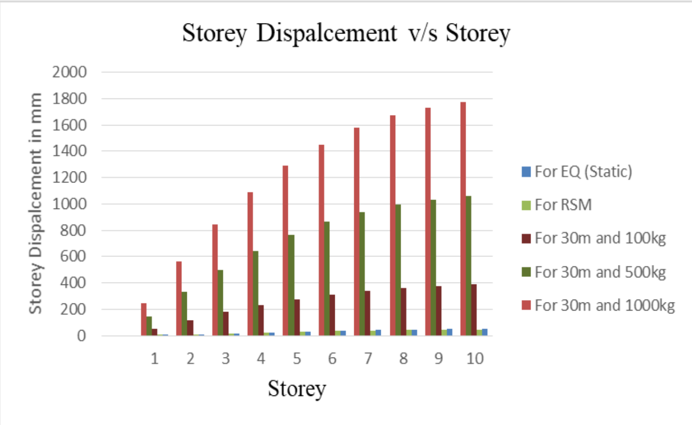

Fig -3.1: Comparison of displacement along the storey for static and dynamic analysis and also various cases of blast.

It is witnessed that displacement is very less in the case of seismic analysis compared to blast analysis. It is also observed that displacement increases when the charge weight of the building is more and is less when weight of an explosive is less. From the table it is observed that displacement at top storey for static, RSM, for 30m standoff distance with 100kg , 500kg and 1000kg charge weight of an explosive are 50.54mm, 45.805mm, 386.647mm, 1057.464mm and 1773.645 mm respectively. The graph for displacement along the height of the structure for different charge weight of the explosive and displacement due to earth quake is shown in fig 3.1 And also it observed that displacement is more in case of blast analysis when compared with seismic analysis (with zone v).

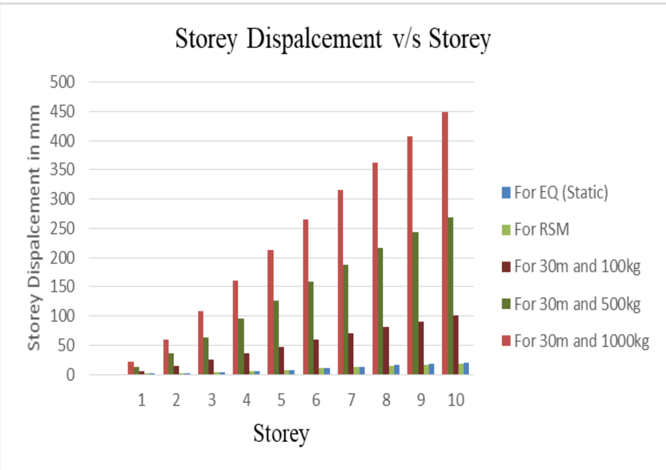

Fig 3.2: Comparison of displacement along the storey for static and dynamic analysis and also various cases of blast.

(With shear wall)

Shear wall is provided to resist the lateral forces of the structure. From the table 3.2it is observed that displacement at top storey for static, RSM, for 30m standoff distance with 100kg , 500kg and 1000kg charge weight of an explosive are 20.226mm, 18.664mm, 100.499mm, 268.759mm and 449.426 mm respectively.

3.2 Storey drift

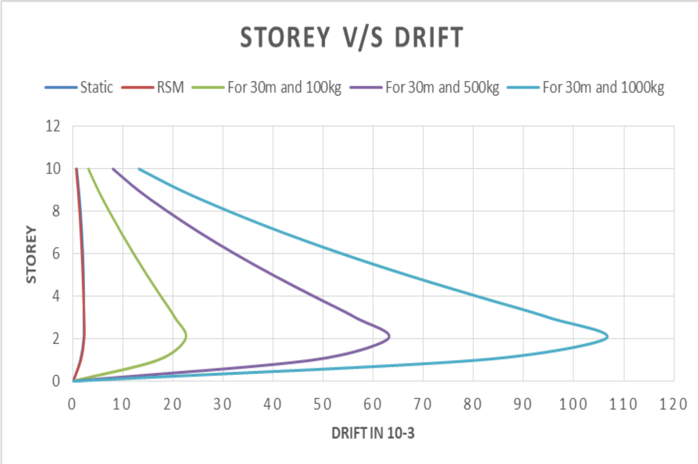

Fig -3.3: Comparison of Storey drift along the storey for static and dynamic analysis and also various cases of blast.

It is observed that drift is more in the case of blast analysis compared with seismic analysis. It is also observed that drift decreases when the charge weight of the building is less and is high when weight of an explosive is more.

3.3 Storey shear

Fig .3.4: Storey Shear of the building for Seismic analysis and also for various cases of blast.

It can be observed that storey shear for the blast analysis is more when compared with the seismic analysis. For the model with 100kg of blast load increment in storey shear is up to 898% when compared with the Earthquake (Zone V)

Model. In the case of model with 500kg of blast load increment in storey shear is up to 182% compared with the 100kg of blast load. In the case of model with 1000kg of blast load increment in storey shear is up to 69.5% compared with the 500kg of blast load.

3.4 Column bending moment

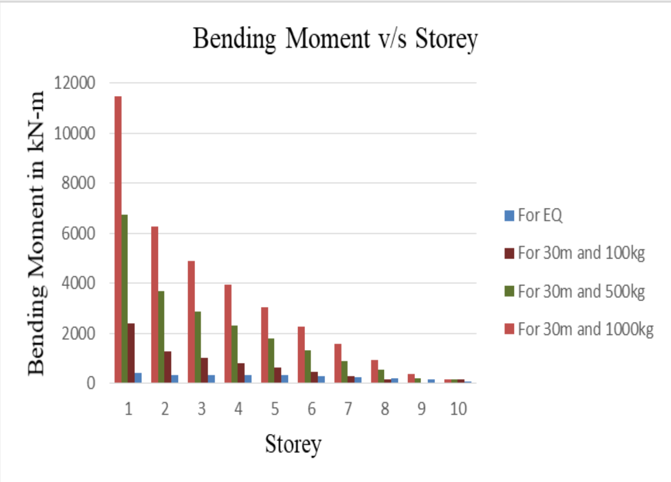

Fig.3.5: Bending Moment of the building for Seismic analysis and also for various cases of blast

It is witnessed that bending moment gradually decreases as the storey height increases. The bending moment at the top storey 171kN-m (at storey 1) in the case bload load at 1000kg weight of explosive increases at the bottom storey is 11451kN-m. And also the bending moment of the column increases when the charge weight of the explosive is more. It is more in case of blast analysis when compared with seismic analysis considered in the study.

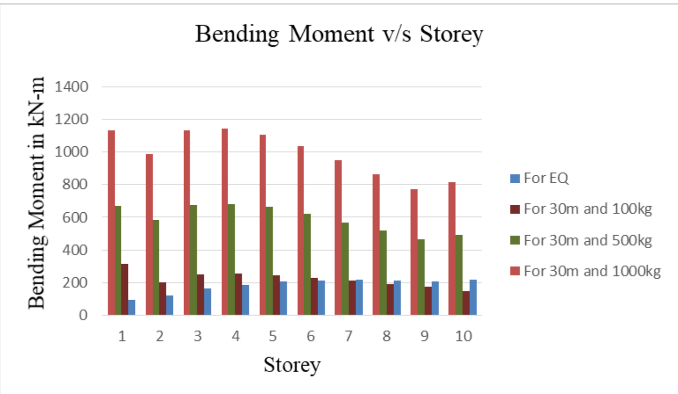

Fig.3.6: Column Bending Moment of the building for Seismic analysis and also for various cases of blast. (With shear wall)

4. COMPARISON

The parameters such as number of members failed, storey displacement and storey drift with and without shear wall for both seismic and blast analysis with a charge weight of 100kg and at a standoff distance of 30m.From the below table 5.10 the structure is weak against the blast action when compared with the seismic action. Thus, by providing shear wall at the corners results the better performance of the building against seismic and blast actions.

Table-4: Number of members failed for Seismic analysis and also for 100kg of blast. (With and without shear wall).

Model with 100kg of charge weight	Total number of Beams	Total number of columns	No of beams failed	No of columns failed	% of Beams Failed	% of columns failed
Builidng without shear wall and for Blast case	660	400	246	322	37	81
Builidng without shear wall and for seismic case	660	400	0	294	0	74
Builidng with shear wall and for Blast case	560	250	9	188	2	75
Builidng with shear wall and for seismic case	560	250	0	147	0	59

Number of members failed due to blast is less when the model is provided with shear wall. Hence the stability of the building is good when building is provided with shear wall and when the thickness of the shear wall increases the stability of the building also increases. It is also observed that displacement and drift of the building is reduced when the building is provided with the shear wall compared with building without shear wall and it is within permissible limit (120mm as per IS:1893-2002).

5. CONCLUSIONS

1. The results obtained from different charge weight shows that the storey displacement, storey drift, column forces and the number of members failed are found to be very high when the structure is subjected to 1000kg of blast load.

2. The pressure due to blast is directly proportional to charge weight of the explosive. The pressure when 1000kg of charge weight is 421% more when compared with 100kg of charge weight.

3. The storey displacement and drift is very important parameter in the performance of the building, storey displacement and drift is within the permissible limit in the case of earth quake load but in the case of blast load storey drift exceeds max permissible limit.

4. The stability of the building is more when the building is provided with shear wall and stability increases when the thickness of the shear wall increases.

5. The number of failed members in the case of charge weight of 1000kg of charge weight is more when compared

in the case of charge weight of 100kg. And also more number of failure member occurs in the blast case than earth quake.

6. The storey shear of the building is more as the charge weight of the building is high and also storey shear is less in the case of earthquake when compared with the blast load.

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