ANALYSIS OF BLAST RESISTANCE STRUCTURE

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Abstract: *The effect of blast load on building is a serious matter that should be taken into consideration in the design. Even though designing the structure to be fully blast resistant is not a realistic and economical option. We can even improve the new and existing building to ease the effect of a blast. In this study we have analysed the effects caused by the blast loads and to find ways to reduce the effects using Etab-2013 software. From these studies we conclude that the variation could be analysed on unsymmetrical structures.*

Keywords: Blast Resistant structures, Stand-off distance, Blast loading, Scaled distance.

1. INTRODUCTION

Since from few years, structures which are subjected to blast loading have got importance hence these are taken into consideration for design. Commonly in conventional building blast load is not considered in design because the magnitude of effect is high, it leads towards uneconomical in both design and construction. Due to blast, the buildings are liable to damage. Due to recent past blast attacks in the country trigger the minds of developers, architects and engineers to find the solution to overcome the blast effects and to avoid the disasters of the buildings.

Tall buildings majorly targeted structure. Tall structures are designed primarily according to the needs of purposeful requirement whether it is commercial, residential or both. The technology developments, the high performance materials discovery, new construction techniques and the upward transportation made possible the building of super tall structures. Some high-rise buildings are built to enhance the prestige of a nation, city or people. Tall buildings are also constructed for many other reasons. In many big cities there is no enough space due to the rapid growth of population and increase in the number of people moving-to the cities. The desire to preserve some land for agricultural purpose, the high cost of land, the demand of business to be as close as possible and some other factors have contributed to drive buildings upward to create more useable space in less land.

1.1 Problem statement

Most buildings are commonly designed for conventional loads. Explosions costs catastrophic damage and the trauma to society can be severe. There is also an increase of threats to structures and terrorists activities due to political and social instabilities in many different parts of the world. An effective security system may reduce to potential threat of an attack, but it will never entirely eliminate its occurrence. Commercial buildings are built quite differently compare to military structures and are vulnerable to blast and ballistic effects. On the other hand, one of the main challenges associated with blast loading is that the information related to blast phenomenon is scattered in many different sources. What is more, certain information in the field of blast effects remains classified and cannot be accessed by all engineers.

Design consideration against explosion is very important in high-rise facilities such as public and commercial tall buildings. Therefore, it is important to gather the available literature review on explosives, blast phenomena, blast wave interaction and response of structures to blast loads.

1.2 Objectives

This study is concerned with the behaviour of tall structures when subjected to external explosion. The objectives are as follows:

1. To understand the behaviour of blast of high rise buildings by response spectrum analysis.
2. Modelling and analysis of high-rise building models for external explosion.
3. Study and compare the behaviour of different building models for analysed results.

1.3 Scope and Limitations of the study

The study focuses on the modelling of a reinforced high rise building using ETABS program and analysing its behaviour when subjected to blast loads. The blast loads are calculated using the IS code IS: 4991-1968. In this study the tall structure is assumed to be isolated loaded by a blast explosion. Two different blast magnitudes of 100kg and 300 kg, stability of the structure is found out at a two different standoff distance of 20m and 30m with R.C. Frame models.

2. METHODOLOGY

2.1 Introduction

Method Used: Response Spectra Analysis.

Response spectrum analysis is nothing but a analysis or calculation of peak response at the time of earthquake without using time history is known as response spectrum analysis. Analysis can be done by using the graph from IS-1893. It is plot of single degree of freedom of response for various values period.

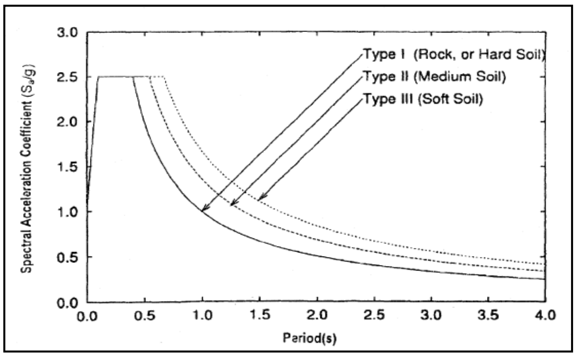

Figure 1.1: Design response Spectrum

2.2 Structural model

In this study, I have considered 12 story building. The area of the building is 96 m². The height of the each story is 3m throughout the model or structure and mass distribution is uniform over the height of the structure. Plan of the building is shown below in figure 3.2 a.

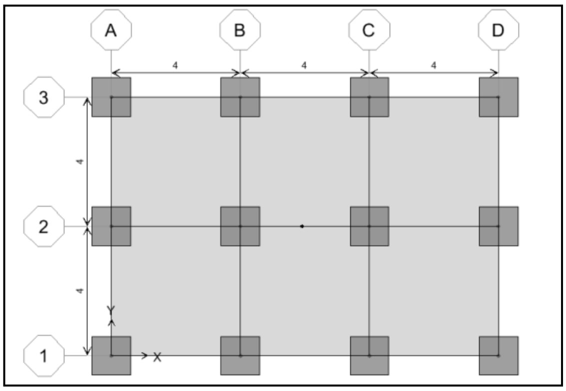

Figure 3.2: Building Plan

2.3 Different Cases for Analysis

Case 1: Blast of 100kg explosive with standoff distance of 30 m

TYPE 1 MODEL - Conventional frame structures.
TYPE 2 MODEL -Conventional frames with increased column & beam sizes.
TYPE 3 MODEL -Conventional frames with addition of shear walls at the corners.
TYPE 4 MODEL -Conventional frames with addition of steel bracing at the corners.

Case 2: Blast of 100kg explosive with standoff distance of 20 m

TYPE 1 MODEL - Conventional frame structures.
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Case 3: Blast of 300kg explosive with standoff distance of 30 m

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Case 4: Blast of 300kg explosive with standoff distance of 20 m

TYPE 1 MODEL - Conventional frame structures.
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TYPE 4 MODEL - Conventional frames with addition of steel bracing at the corners.

Table 3.1: Cases Detailing of Different Models

	STANDOFF DISTANCE (m)	BLAST LOAD (kg)	TYPE OF MODEL	COLUMN SIZES (mm)	BEAM SIZES (mm)
Case 1	30	100	1 ,3 and 4	1200X1200	1200X800
			2	1500X1500	1500X900
Case 2	20	100	1 ,3 and 4	1000X1000	200X650
			2	1850X1850	1850X900
Case 3	30	300	1 ,3 and 4	1800X1800	1800X800
			2	1950X1950	1950X900
Case 4	20	300	1 ,3 and 4	3000X3000	2000X800
			2	3000X3000	2000X900

2ISMB600 is used for bracing system.
Shear wall thickness is 200mm
SEISMIC LOADING ZONE AS PER IS-1893

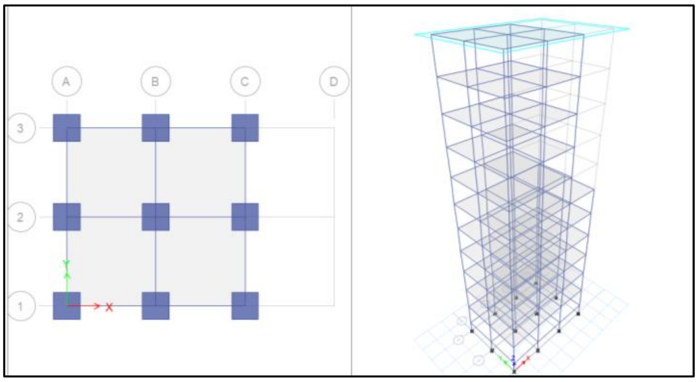

Figure 3.3: Type 1 Model

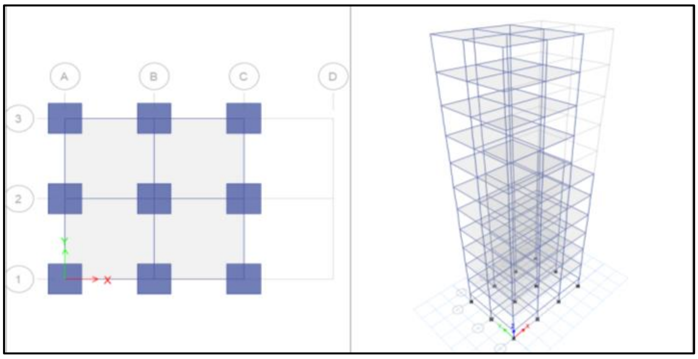

Figure 3.4: Type 2 Model

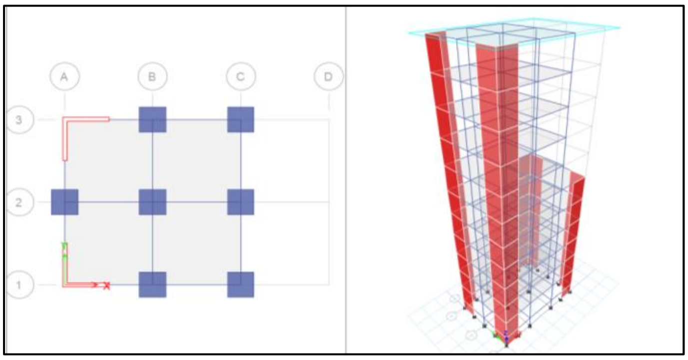

Figure 3.5: Type 3 Model

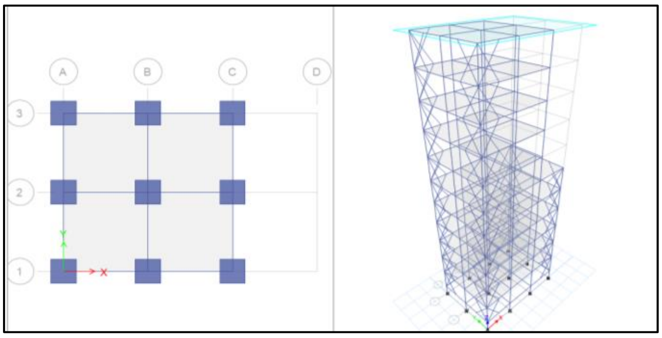

Figure 3.6: Type 4 Model

2.4 Input details

Table 3.2: Earthquake parameter

Detail	Value
R	3
I	1
Z	III
Sa/g	2

Where,
Z = Zone R = response reduction factor
Sa/g = Soil type II I = Importance factor

Table 3.3: Grade of Concrete

MODEL TYPEMATERIAL PROPERTIES	ALL Model
Column / Wall	M40
Beam	M35
Slab	M25

Thickness of the slab is 150mm.
Thickness of the wall is 200mm.
Unit weight of concrete is $25kN/m^3$.

2.5 Static load assignment

Dead Load, Live Load, Floor Finish, and Earth Quake Load these are the loads considered in all 4 models.

i. **Dead Load:** This load is considered from IS-875 part 1-1987 (Table 1). Unit weight of RCC is $24.80kN/m^3$-26.50 KN/m^3. From the code book, $25kN/m^3$is considered as unit weight of RCC. Dead load includes the self-weight and floor finish of 1.5 KN/m^2.

ii. **Imposed Load**: this load is obtained from code book IS-875-1987 (PART 2) table 1. $4.0kN/m^2$ is assumed as the UDL on the building.
On roof 1.5 KN/m^2, and
On floors 4.0 KN/m^2

iii. **Earthquake Load**: As per code IS 875-1987 part2 from Table1. The structure is assumed to be in Zone-II. As per Table 2 of IS 1893 – 2002 zone factor is considered. 5% damping is assumed, 1 as importance factor considered from table 6 of IS 1893-2002. Response reduction factor R is considered as 3 in this case.

Soil type II, Importance factor is 1.

2.6 Load combinations:

The combination of load is taken from code IS 1893-2002 page 13.
DL earthquake in x direction= (DL+LL+FF+SPECX) 1.2
DL earthquake in y direction= (DL+LL+FF+SPECY) 1.2

Table 3.4: Blast load calculation

	CASE1	CASE2	CASE3	CASE4
Blast Of (kg)	100	100	300	300
Standoff Distance (m)	30	20	30	20
Scaled Distance (m)	64.13	42.75	44.63	29.75
PU	I	I	I	I
P_{so}	0.35	0.71	0.67	1.41
P_{ro}	0.81	1.81	1.68	4.26
q_o	0.042	0.61	0.14	0.50
t_o	17.5	30.61	20.85	24.21
t_d	13.15	20.96	14.4	15.93
M	1.14	1.26	1.25	1.72
a	344	344	344	344
U	0.39	0.43	0.43	0.59
Bay Spacing (m)	4	4	4	4
H	12	12	12	12
B	8	8	8	8
L	12	12	12	12

S	12	12	12	12
Story Ht (m)	3	3	3	3
t_c	91.79	82.79	83.72	60.84
t_c	30.59	27.59	27.90	20.28
t_r	122.39	110.39	111.62	81.12
for roof and sides C_d	-0.4	-0.4	-0.4	-0.4
$P_{so}+C_d(q_o)$	0.33	0.47	0.61	1.21
Loads on front face joints (kg/m²)				
L On Center joint	972	2180.4	2016	5112
L On Side Joints	486	1090.2	1008	2556
L On Edge Joints	243	545.1	504	1278
Loads on Roof & side walls (kg/m²)				
L On Center joint	399.84	565.44	734.4	1457.32
L On Side Joints	199.92	282.72	367.2	728.66
L On Edge Joints	99.96	141.36	183.6	364.33

2.7 Analysis input

Table 3.5: Response spectra analysis input for all 4 types of models.

TYPES OF MODELS	ALL MODEL
R VALUE	3
Importance factor	1.0
structural and function damping	0.05
model combination	CQC
directional combination	SRSS
response spectra input	(9.81)/(2)(3)
eccentricity ratio	0.05

3. RESULTS & DISCUSSION

Case-1: Blast of 100kg explosive with standoff distance of 30m.

3.1 Frequency and Time Period

3.1.1 Time Period (sec)

Table 4.1: Time Period vs Modes

	TP-T1.1	TP-T1.2	TP-T1.3	TP-T1.4
1	0.560531	0.471301	0.480266	0.471096
2	0.496807	0.416548	0.430791	0.42576
3	0.346143	0.281978	0.221467	0.264785
4	0.183875	0.15142	0.152155	0.160299
5	0.180294	0.148629	0.146586	0.155097
6	0.143775	0.11561	0.090726	0.112793
7	0.091443	0.074044	0.073187	0.076948
8	0.090099	0.073164	0.071147	0.076486
9	0.075406	0.060487	0.051194	0.058568
10	0.060171	0.047894	0.047364	0.053653
11	0.059412	0.047386	0.04645	0.051116
12	0.052497	0.041516	0.035098	0.041786

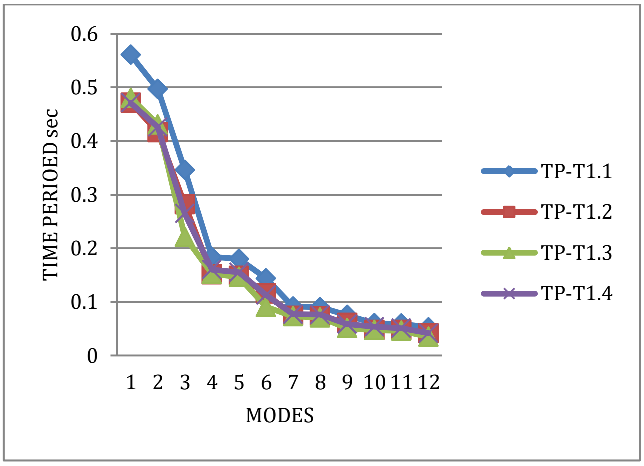

Figure 4.1: Time Period vs modes

As we can see in the above values the time period gradually decreases as the modes increases. When the time periods are compared with four different models it is seen that the time period is more in model 1 while least in model 3. The graph is then plotted time period with respect to modes.

3.1.2 Frequency (cyc/sec)

Table 4.2: Frequency vs Modes

	FR-T1.1	FR-T1.2	FR-T1.3	FR-T1.4
1	1.784023	2.121786	2.082179	2.12271
2	2.012854	2.400684	2.321311	2.348741
3	2.888979	3.546376	4.515345	3.776649
4	5.438477	6.604147	6.572245	6.238342
5	5.546496	6.728162	6.821934	6.447578
6	6.955312	8.649771	11.0222	8.865798
7	10.93577	13.50548	13.66363	12.99579
8	11.0989	13.66792	14.05541	13.07429
9	13.26154	16.53248	19.53354	17.07417
10	16.6193	20.87944	21.11308	18.63829
11	16.83162	21.10328	21.52853	19.56335
12	19.04871	24.0871	28.49165	23.93146

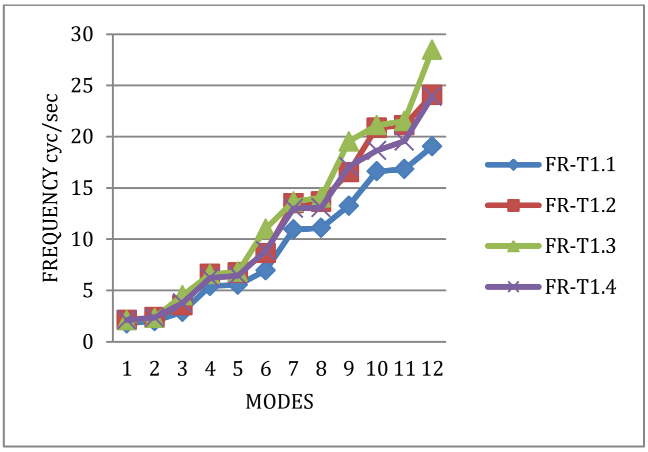

Figure 4.2: Frequency vs Modes

As we can see in the above values the Frequency gradually increases as the modes increases. When the frequencies are compared with four different models it is seen that the frequency is more in model 3 while least in model 1. The graph is then plotted frequency (cyc/sec) with respect to modes.

3.2 Displacement (mm):

3.2.1 Earthquake In X-Direction

Table 4.3: Displacement vs Storey Level (X-Direction)

	UX-T1.1	UX-T1.2	UX-T1.3	UX-T1.4
11th	4.4561	2.8648	2.9899	3.2512
10th	4.1665	2.6646	2.7567	2.9702
9th	3.8181	2.4271	2.4815	2.6473
8th	3.4184	2.1572	2.1768	2.2944
7th	2.9918	1.8729	1.8602	1.934
6th	2.5983	1.6156	1.5806	1.6278
5th	2.2558	1.4017	1.3745	1.4251
4th	1.8543	1.1529	1.1317	1.1885
3rd	1.4049	0.8718	0.8586	0.9156
2nd	0.925	0.5704	0.5698	0.618
1st	0.45	0.2746	0.2859	0.316
GF	0	0	0	0

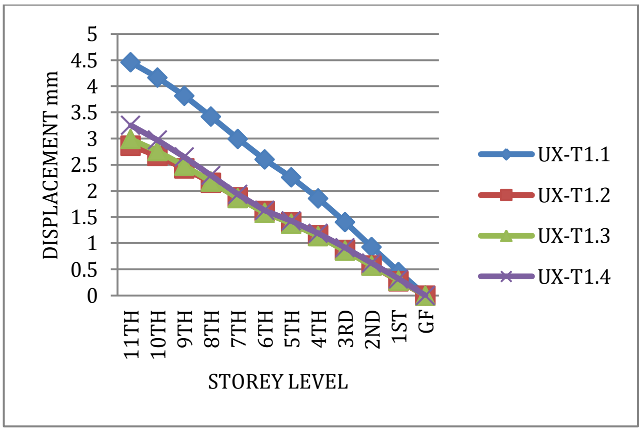

Figure 4.3: Displacement vs Storey Level (X-Direction)

As we can see in the above values the displacement gradually decreases as the storey level decreases showing zero at ground floor. When the displacement are compared with four different models it is seen that the displacement is more in model 1 while the displacements are less up to 7th storey level in model 3 when compared to model 2 and vice versa beyond this level. This is because of the unsymmetrical structure. Displacements are less in model 3 when compared to model 4. The graph is then plotted displacement (mm) with respect to storey level.

3.2.2 Earthquake in Y-Direction

Table 4.4: Displacement vs Storey Level (Y-Direction)

	UY-T1.1	UY-T1.2	UY-T1.3	UY-T1.4
11th	86.4205	50.3247	73.7786	61.2324
10th	81.9795	47.4779	68.4305	57.4415
9th	76.7328	44.2026	62.4615	53.0501
8th	70.552	40.4251	55.8088	48.0136
7th	63.4841	36.1706	48.6013	42.4217
6th	53.6098	30.4451	40.5273	35.4206
5th	45.5944	25.6345	33.7605	29.8294
4th	37.1926	20.6899	26.984	24.2306
3rd	28.0498	15.4	20.0358	18.299
2nd	18.4052	9.9369	13.0926	12.1584
1st	8.8961	4.711	6.4887	6.1218
GF	0	0	0	0

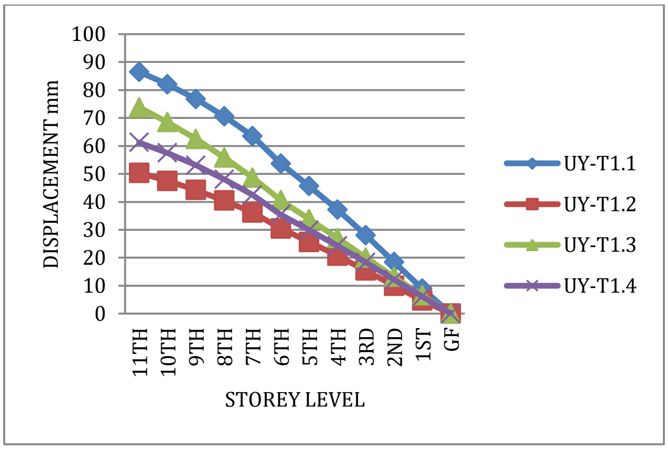

Figure 4.4: Displacement vs Storey Level (Y-Direction)

As we can see in the above values the displacement gradually decreases as the storey level decreases showing zero at ground floor. When the displacement are compared with four different models it is seen that the displacement is more in model 1 while the displacements are less in model 2 because the size of columns and beams are heavy when compared to model 3 and 4. When the models with shear wall and bracings (3 and 4 respectively) are compared it is seen that the displacements are less in model 4. The graph is then plotted displacement (mm) with respect to storey level.

3.3 Story Drift Ratio:

3.3.1 Earthquake in X-Direction

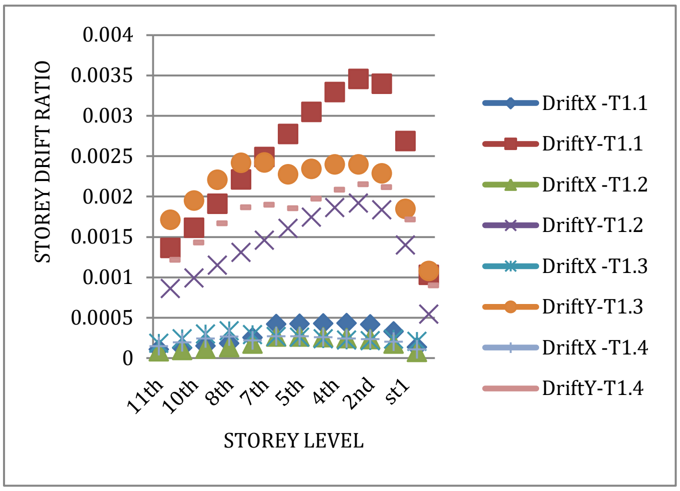

Figure 4.5 a: Drift Ratio vs Storey Level (X-Direction)

3.3.2 Earthquake in Y-Direction

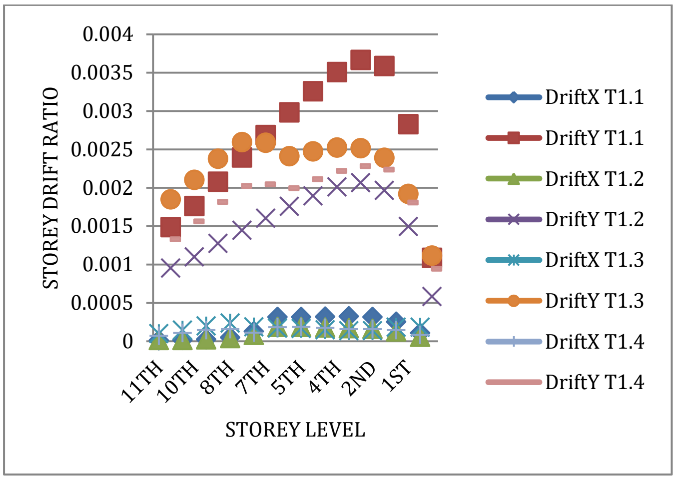

Figure 4.5 b: Drift Ratio vs Storey Level (Y-Direction)

As we can see in the above values the storey drift ratio are compared with four different models, for earthquake in both X and Y directions the storey drift ratio is more in model 1 and less in model 2. When the 3 and 4th models are compared the storey drift are less in model 4.

3.4 Story Shear (kN):

3.4.1 Earthquake In X-Direction

Table 4.5: Storey Shear vs Storey Level (X-Direction)

	VX-T1.1	VX-T1.2	VX-T1.3	VX-T1.4
11th	280.92	324.33	264.96	289.67
10th	460.53	559.18	420.04	476.2
9th	615.93	761.59	550.97	635.52
8th	749.77	934.9	661.05	770.65
7th	863.86	1081.93	752.99	884.07
6th	512.64	765.1	371.24	531.31
5th	630.04	914.98	458.86	649.01
4th	728.28	1040.16	532.19	748.1
3rd	805.52	1137.95	589.85	826.48
2nd	859.63	1205.4	630.37	881.97
1st	887.72	1239.69	651.89	911.72
GF	891.07	1243.97	654.51	915.78

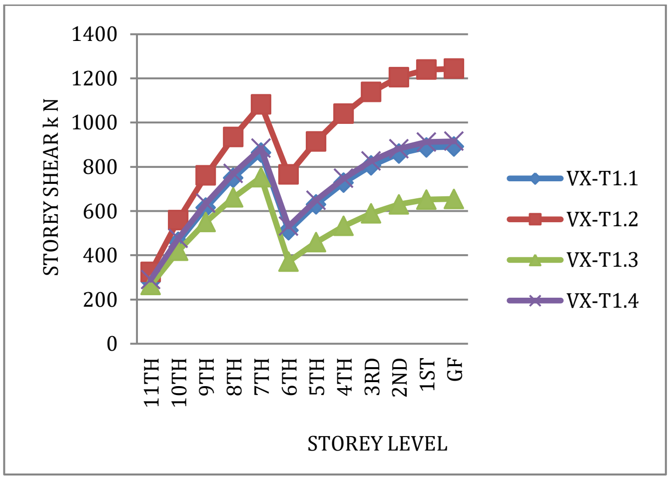

Figure 4.6: Storey Shear vs Storey Level (X-Direction)

As we can see in the above values the storey shear which are compared with four different models, for earthquake in X direction the storey shear is more in model 2 and less in model 3. When the 3 and 4th models are compared the storey shear are less in model 3 which is due to the provision of shear walls.

3.4.2 Earthquake in Y-Direction

Table 4.6: Storey Shear vs Storey Level (Y-Direction)

	VY-T1.1	VY-T1.2	VY-T1.3	VY-T1.4
11th	-896.7	-849.93	-902.64	-880.48
10th	-3057.28	-2953.58	-3080.64	-3028.98
9th	-5241.03	-5088.65	-5283.26	-5204.22
8th	-7445	-7251.54	-7507.69	-7403.37
7th	-9667.15	-9439.33	-9751.15	-9624.05
6th	-12175.2	-11912.7	-12283.7	-12130.5
5th	-15569.7	-15275.5	-15700.9	-15521.7
4th	-18981.1	-18660.7	-19130.5	-18929.2
3rd	-22410.8	-22070.4	-22574.6	-22355.2
2nd	-25860.9	-25507.6	-26035	-25802.3
1st	-29334.6	-28975.4	-29513.5	-29273.4
GF	-31081.2	-30721.2	-31260.6	-31019.2

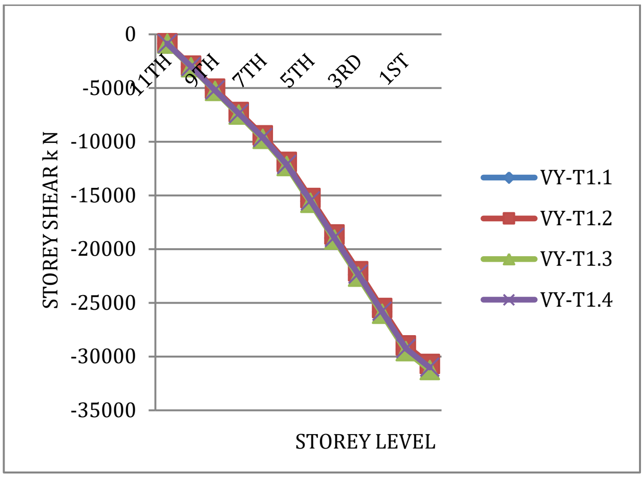

Figure 4.7: Storey Shear vs Storey Level (Y-Direction)

As we can see in the above values the storey shear which are compared with four different models, for earthquake in Y direction the storey shear is more in model 1 up to storey level 6 while it is more in model 3 beyond this storey level and overall it is less in model 2. When the 3 and 4th models are compared the storey shear are less in model 4 which is due to the provision of bracings.

4. CONCLUSIONS

Time period:

- As the storey level increases the time period increases
- When time period of all the types are compared it is found that Type 3 model is having the least value, which is having shear wall.

Frequency:

- As the storey level increases the frequency decreases.
- When frequency of all the types is compared it is found that Type 3 model is having the higher value, which is having shear wall.

CASE 1: Displacement:

Earthquake analysis of a tall building for **Blast of 100kg explosive with standoff distance of 30 m** has given an idea how the different types of tall building like, Type 1, Type 2, Type 3 and Type 4 behaves during the Earth quake. It is seen that the Earthquake response in x & y direction is reduced in the Building with increase column - beam sizes.

Storey Drift:

The storey drift is less in Type 2 model compared to other models.

CASE 2: Displacement:

Earthquake analysis of a tall building for **Blast of 100kg explosive with standoff distance of 20 m** has given an idea how the different types of tall building like, Type 1, Type 2, Type 3 and Type 4 behaves during the Earth quake. It is seen that the Earth quake response in x direction is reduced in the Building with increase column - beam sizes. And in y direction, the Building with shear walls located at corners has shown the reduction.

Storey Drift:

The storey drift is less in Type 3 model compared to other models.

CASE 3: Displacement:

Earthquake analysis of a tall building for **Blast of 300kg explosive with standoff distance of 30 m** has given an idea how the different types of tall building like, Type 1, Type 2, Type 3 and Type 4 behaves during the Earth quake. It is seen that the Earth quake response in x & y direction is reduced in the Building with increase column - beam sizes.

Storey Drift:

The storey drift is less in Type 2 model compared to other models.

CASE 4: Displacement:

Earthquake analysis of a tall building for **Blast of 300kg explosive with standoff distance of 20 m** has given an idea how the different types of tall building like, Type 1, Type 2, Type 3 and Type 4 behaves during the Earth quake. It is seen that the Earth quake response in x & y direction is reduced in the Building with bracing located at corners.

Storey Drift:

The storey drift is less in Type 4 model compared to other models.

4.1 Overall Conclusion

- By increasing column and beam size in a structure will improve the resistance but it is not practical in most cases due to serviceability problems because huge cross section of beam and column needed to resist blast loads.
- Addition of shear wall and bracing helps to resist the blast loads effectively.
- The addition of steel bracings gives good results but shear wall more desirable results than steel bracings and it is economical too compared to other methods.

4.2 Further work Recommendations

It is recommended that further research can be undertaken in following areas

1. Compare the wind response of conventional tall regular building with tall regular (having different location of shear walls) building, by doing Dynamic wind analysis to assess the exact response.

2. Compare the Dynamic wind response of conventional tall irregular building with tall irregular (having different location of shear walls) building, by using Static and Dynamic wind analysis.

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