Structural Analysis of Blast Resistant Buildings

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Abstract: The objective of this study is to shed light on blast resistant building design theories. The general aspects of explosion process have been presented to clarify the effects of explosives on buildings. The main aim of this work is to compare the responses of the structure having shear wall and the structure having braces. Thus, analysing which structure is more blast resistant. Blast loads of explosives weighing 150kg and 250kg is subjected on both the models at distances 25m & 50m. Responses of both the models are observed.

INTRODUCTION

An explosion can be defined as rapid liberation of potential energy followed by huge eruption of energy in the atmosphere. The energy released during explosion is converted into thermal energy radiation and some part of energy forms shock waves which expand radially.

Many incidents have taken place around the world where the structures are subjected to blast induced impulsive loads due to fanatic activities in the past few years. This has lead to threat to life and property. Blast resistant design is a specialized area to which structural engineers are not exposed meticulously as this design is comprehensively used only for military setups. Various types of finite element tools and software are available for blast resisting design of structures.

STRUCTURAL ASPECTS OF DESIGN FOR BLASTS LOADING

Whenever an explosion takes place the front face of the building experiences maximum over pressure due to reflection. The sides and terrace of the building experiences no reflected waves. The back side of the building experiences zero pressure unless the blast wave has travelled throughout the structure. There will be a lag of time in the formation of pressure and loads on the front and back sides.

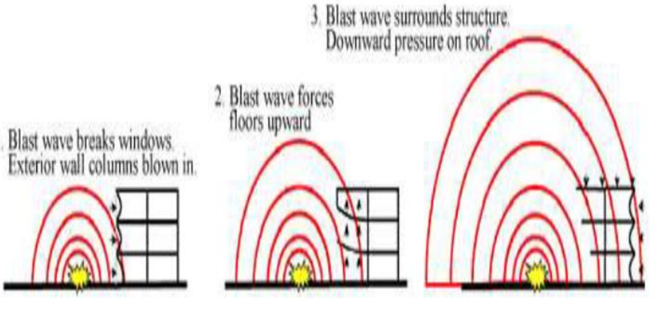

Fig 1: Blast effects

LITERATURE REVIEW

R.D. Ambrosini & B M Luccioni (2003): They conducted study on reinforced concrete building and did the analysis of structural failure due to blast load. The whole process of explosion charge to the complete destruction of the structure is reproduced, including the proliferation of blast wave and its effects on the structure. Their journal includes comparison that the damage occurred by explosive charge with images along with the simulation procedure.

Mayor Baxani et al. (2015): He studied the dynamic response of Masonry wall subjected to blast load of charge 0.5kg at a distance of 0.5m from the wall. Langrangian and Eulerian methods are incorporated to implement the required parameters of blast load. Finite Element analysis tool Autodyne was used. The idea of this work was to investigate the local effect and global response of the masonry wall. The analysis results were obtained in terms of acceleration, velocity for charges on the ground and in air, it was found that the maximum acceleration for both air blast and ground blast 11.772 mm/s^2 and 8.14 mm/s^2 respectively.

METHODOLOGY

The calculations are based on **IS: 4991-1968** which is the criteria for blast resistant design of structures for explosions above ground.

Models used:

Model 1: Shear wall of thickness 150mm
Model 2: Structure having Braces of Steel

Case Study:

Case 1- Blast load of 150kg explosive at 25m standoff distance
Case 2- Blast load of 150kg explosive at 50m standoff distance
Case 3- Blast load of 250kg explosive at 25m standoff distance
Case 4- Blast load of 250kg explosive at 50m standoff distance

STRUCTURAL DETAILS

Description of Model:

Table 1: Description of Model	
No. of bays in x-direction	4
No. of bays in y-direction	4
Width of single bay in both directions	4m
No. of Storeys	20
Height of each storey	3m

Structural elements:

Table 2: Structural Elements		
Column	600mm x 600mm	M40
Beam	350mm x 550mm	M30
Slab	140mm thick	M30
Plinth	900mm thick	M30
Steel		Fe 500

General loading:

Table 3: Loadings	
Live load	$3 kN/m^2$
Floor finish	$1.5 kN/m^2$
Imposed loads	$2 kN/m^2$

Model 1: shear walls of 150mm thickness is used

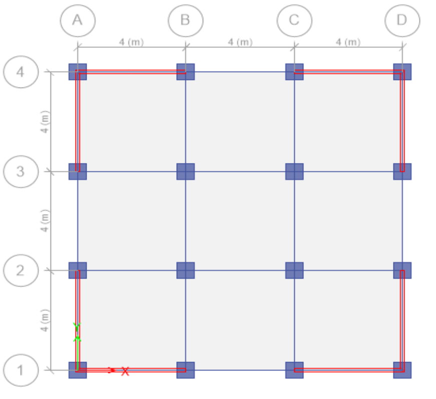

Fig 2: Plan view

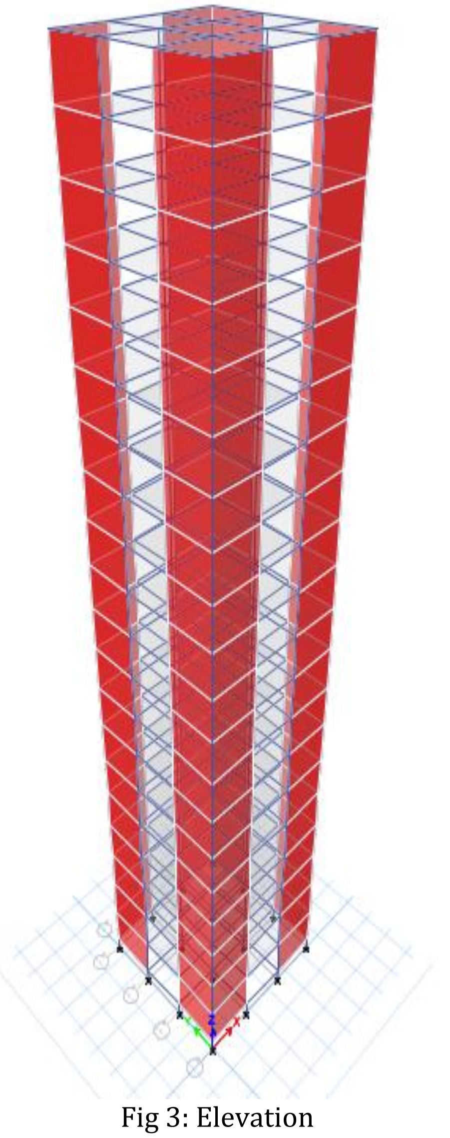

Fig 3: Elevation

Model 2: Steel bracing of X-shape. ISWB550 steel has been used.

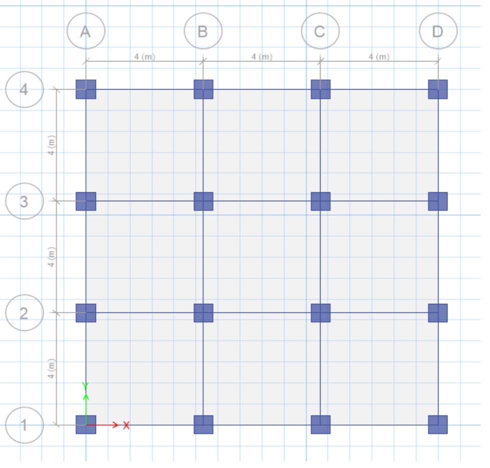

Fig 4: Plan view

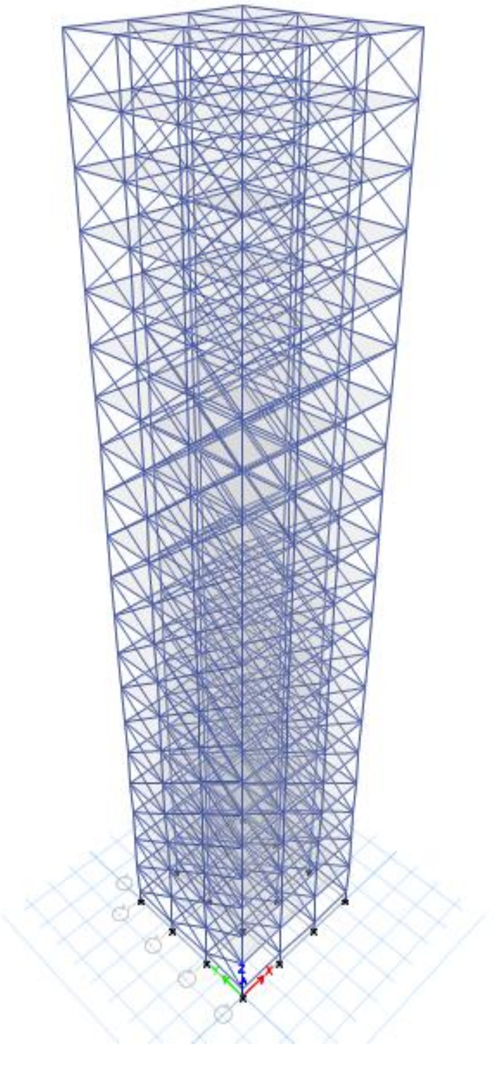

Fig 5: Elevation

RESULTS:

Case 1: when 150kg of explosive is used at 25m standoff distance

Storey displacement

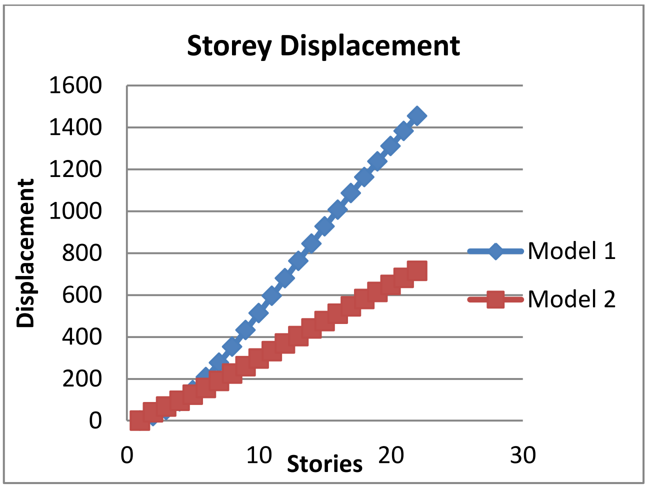

Fig 6: Comparison of Storey Displacement

Table 4: Storey Displacement	Model 1	Model 2
Storeys	mm	mm
Base	0	0
PLINTH	21.4	40.3
Story1	49.7	67.7
story2	91.1	94.9
Story3	144.5	124.1
Story4	207.2	155.9
Story5	277.1	189.4
Story6	352.5	224.2
Story7	431.6	259.8
Story8	513.2	295.9
Story9	596.1	332.2
Story10	679.3	368.7
Story11	762.7	403.5
Story12	845.2	439.2
Story13	926.8	474.9
Story14	1006.9	510.4
Story15	1085.5	545.6
Story16	1162.3	580.4
Story17	1237.5	614.7
Story18	1311	648.4
Story19	1383	681.6
Story20	1453.9	714.2

Storey Drift

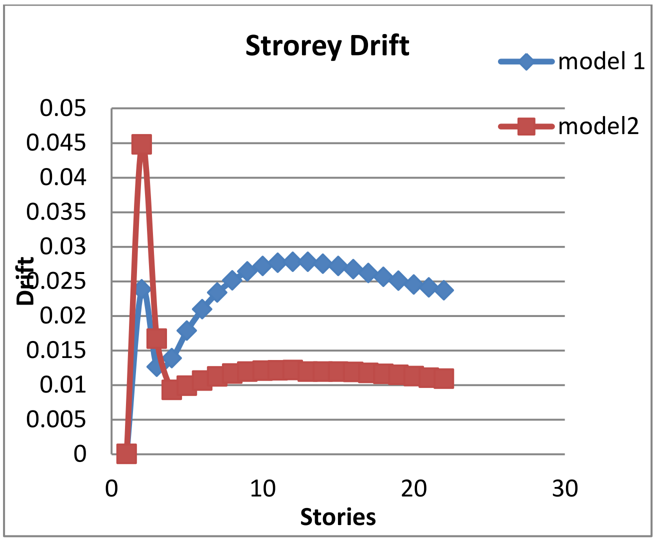

Fig 7: Comparison of Storey Drift

Table 5 : Storey Drift	Model 1	Model 2
Storeys		
Base	0	0
Plinth	0.02382	0.044747
1	0.012601	0.016684
2	0.013856	0.009288
3	0.01783	0.009887
4	0.020938	0.010624
5	0.023338	0.011205
6	0.025124	0.011619
7	0.026383	0.011896
8	0.027196	0.012053
9	0.027641	0.012108
10	0.027791	0.012155
11	0.02778	0.011921
12	0.027532	0.011922
13	0.027177	0.011909
14	0.026718	0.011846
15	0.026188	0.011743
16	0.025621	0.011605
17	0.025052	0.01144
18	0.024511	0.011255
19	0.024066	0.011057
20	0.023682	0.010878

Case 2: when 150kg explosive used at 50m standoff distance.

Storey Displacement

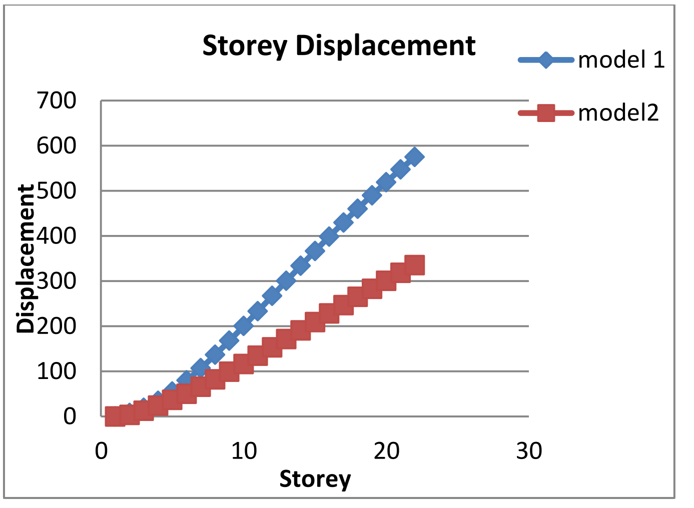

Fig 8: Comparison of lateral displacement

Table 6: Storey Displacement	Model 1	Model 2
Storeys	mm	mm
Base	0	0
PLINTH	7.9	3.3
1	18.7	12.5
2	34.8	23.7
3	55.3	36.3
4	79.7	50.3
5	107	65.6
6	136.6	81.8
7	167.8	98.8
8	200.3	116.4
9	233.4	134.6
10	266.9	153
11	300.4	171.7
12	333.6	190.5
13	366.3	209.3
14	398.4	228.1
15	429.8	246.6
16	460.4	265
17	490.2	283
18	519.2	300.8
19	547.5	318.2
20	575.1	335.3

Storey Drift

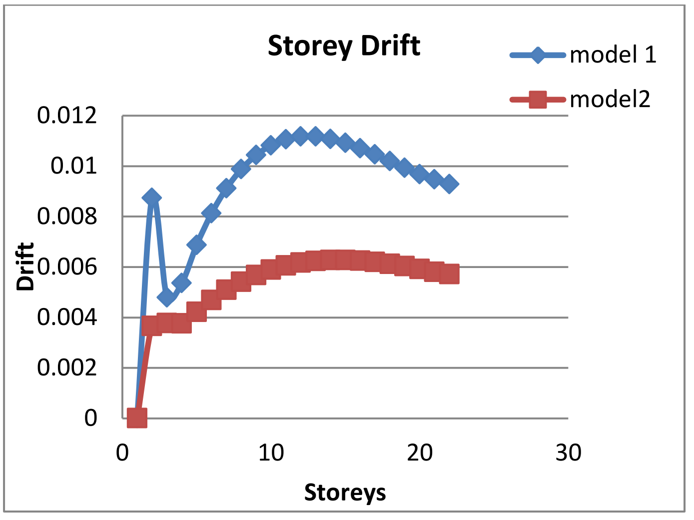

Fig 9: Comparison of Storey drift

Table 7: Storey Drift	Model 1	Model 2
Storeys		
Base	0	0
PLINTH	0.008729	0.003665
1	0.004794	0.003771
2	0.005358	0.003764
3	0.006873	0.004221
4	0.008124	0.004692
5	0.009114	0.005088
6	0.009874	0.005416
7	0.010434	0.005683
8	0.010821	0.005894
9	0.011057	0.006054
10	0.011165	0.006168
11	0.011165	0.00624
12	0.011076	0.006275
13	0.010916	0.006276
14	0.010704	0.006247
15	0.010458	0.006193
16	0.010192	0.006118
17	0.009925	0.006026
18	0.009671	0.005921
19	0.009466	0.005808
20	0.009275	0.005711

Case 3: when 250kg of explosive is used at 25m standoff distance.

Storey Displacement

Fig 10: Comparison of lateral displacement

Table 8: Storey Displacement	Model 1	Model 2
Storeys	mm	mm
Base	0	0
PLINTH	11.1	48
1	46	97.5
2	99.9	151.1
3	166.8	211.6
4	244.7	279.3
5	331.1	352.7
6	423.5	430.8
7	520	512.8
8	619.1	597.9
9	719.4	685.4
10	819.6	774.4
11	918.7	864.6
12	1016.2	955.3
13	1111.3	1046
14	1203.6	1136.4
15	1293	1225.9
16	1379.2	1314.4
17	1462.5	1401.6
18	1542.8	1487.3
19	1620.8	1571.4
20	1695.9	1654.1

Storey Drift

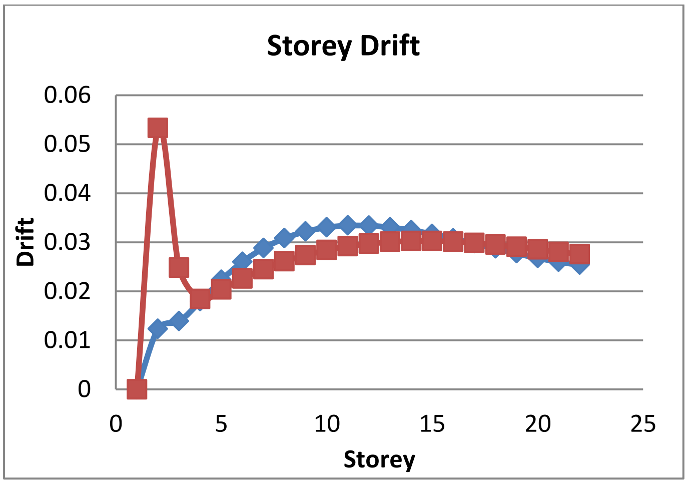

Fig 11: Comparison of Storey drift

Table 9: Storey Drift	Model 1	Model 2
Storeys		
Base	0	0
PLINTH	0.012332	0.053297
1	0.013897	0.024798
2	0.017958	0.018405
3	0.022339	0.020365
4	0.02603	0.022616
5	0.028824	0.024531
6	0.030854	0.026112
7	0.032237	0.027399
8	0.033069	0.028419
9	0.033437	0.029194
10	0.033418	0.029747
11	0.033081	0.030099
12	0.032493	0.030269
13	0.031711	0.030277
14	0.030792	0.030143
15	0.029789	0.029886
16	0.028755	0.029526
17	0.027744	0.029083
18	0.0268	0.02858
19	0.026029	0.028042
20	0.025406	0.027566

Case 4: when 250kg explosive is used at 50m standoff distance.

Storey Displacement

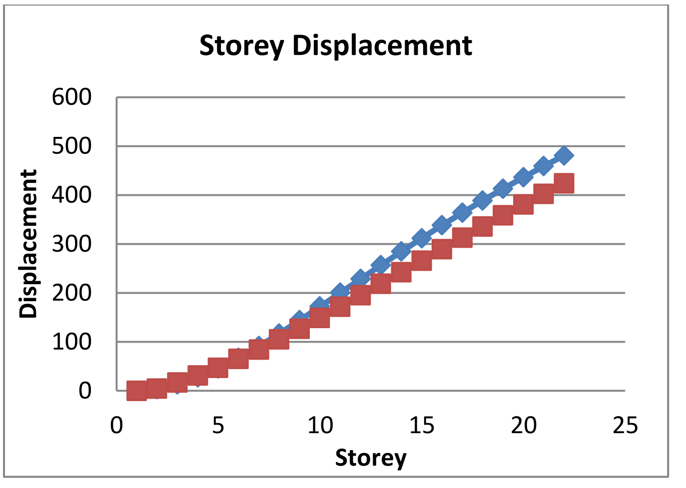

Fig 12: Comparison of lateral displacement

Table 10: Storey Displacements	Model 1	Model 2
Storeys	mm	mm
Base	0	0
PLINTH	3.3	4.7
1	12.8	16.6
2	27.4	31
3	45.8	47
4	67.3	64.9
5	91.3	84.3
6	117.1	104.9
7	144.1	126.4
8	172	148.8
9	200.3	171.7
10	228.6	195
11	256.8	218.6
12	284.5	242.2
13	311.7	265.9
14	338.2	289.4
15	363.8	312.7
16	388.7	335.8
17	412.8	358.4
18	436.1	380.6
19	458.9	402.4
20	480.8	423.9

Storey Drift

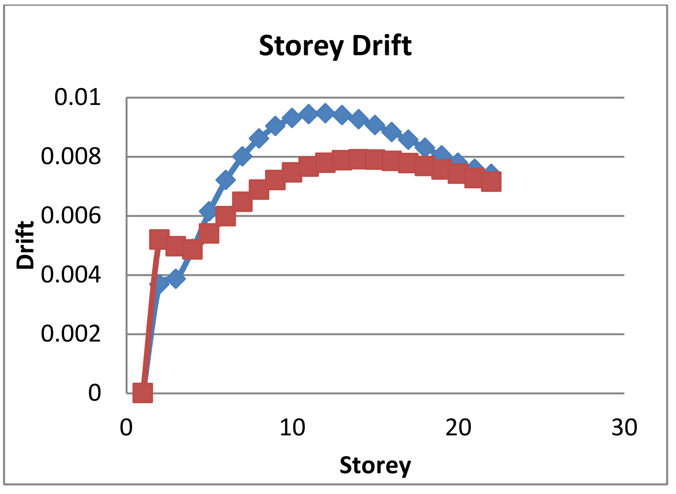

Fig 13: Comparison of Storey drift

Table 11 : Storey Drift	Model 1	Model 2
Storeys		
Base	0	0
PLINTH	0.003681	0.005192
1	0.00386	0.004963
2	0.004874	0.004854
3	0.006141	0.005395
4	0.007196	0.00598
5	0.008006	0.00647
6	0.008607	0.006874
7	0.009028	0.0072
8	0.009295	0.007457
9	0.009431	0.00765
10	0.009457	0.007785
11	0.009391	0.007868
12	0.009253	0.007903
13	0.009059	0.007897
14	0.008824	0.007854
15	0.008564	0.007778
16	0.008294	0.007677
17	0.008028	0.007554
18	0.00778	0.007416
19	0.00758	0.007268
20	0.007407	0.007144

CONCLUSIONS

1) With the increase in Blast load and decrease in the Standoff distance, the Displacement and Storey Drift increases rapidly. So the response of the structure completely depends on the standoff distance and blast load.
2) The maximum displacements are 1695.9mm and 1654.1mm for 250kg explosive from 25m standoff distance. And 1453.9mm & 714.2mm was the maximum displacement for 150kg explosive at 25m standoff distance.
3) For model 2 having steel braces the storey displacement is reduced to 58% and storey drift are reduced to 52.2% for 150kg of explosive.
4) Here, while using 250kg of explosive the thickness of shear wall was increased to 250mm but the grade of concrete used is M40 only.
5) In case 3 and case 4, where the thickness of shear wall is increased (Model 1) the difference in the response of both the models was effectively reduced.
6) The responses of both Model 1 and Model 2 at their respective distances are obtained.

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