Response of Tall Structures Along Face Exposed to Blast Load Applied at Varying Distance

Shobha R, Vinod B R, Anusha P Prabhu, Shubhashree G R, Yaksha V

Abstract: Blast loads caused by explosives are unexpected loads. These loads cause huge damage to the structure and decrease the strength and durability of structure, especially for elevated buildings. Therefore study of such loads is of major importance. In the present study, G+10 floors with second, third and end bays is modelled using ETABS and sudden impact dynamic load analysis is carried out. The analysis is carried out on the face directly exposed to the blast load for 7 building models. The blast loads are obtained with the help of TM5-1300 manual as well as ATBLAST software and Structure is designed in ETABS software by non-linear time history analysis. The results of this study help in understanding the behaviour of tall structures in terms of drift, displacement, joint acceleration and shear. Observations show that Model 7 is found to have extreme shear, storey displacement and inter-story drift. The research on examination of tall structures subjected to explosion is helpful in coming up with a better, cost-effective design for blast resistant structures.

***Keywords*: Explosives, ETABS drift, displacement.**

I. INTRODUCTION

As explosions are becoming common in metropolitan cities consideration of blast loads on tall structures is necessary. In recent years blast load investigation would be usually done for military building by specialists. Unstable impact burden results from outrageous occasions, which are not the same as seismic tremor, effect or high wind. A rapid increase in volume and release of energy in an outrageous manner, usually with extremely high temperature and arrival of gases is described as blast load impact.

Blasts either happen as deflagration or explosion depending upon consuming speed during the blast. An explosion is a rapid release of energy in an extreme manner, usually with release of combusted gases. Supersonic explosives are known as detonations and subsonic explosions are known as deflagration**.** Explosion is rapid and destructive process than detonation and deflagration as its peak pressure can be as high as 1000000bar.

An explosive material is a responsive substance which produces blast if discharged all of a sudden.

Based on sensitivity they can be categorized as Type-1, Type-2 and Type-3.

- Type-1: These are more delicate than PETN (Pentaerythritol tetranitrate) and are used to trigger the less delicate explosives.
- Type-2: They need more energy to and are less delicate than Type-1. They are used to trigger Type-3 explosives. Example: Dynamite and RDX
- Type- 3: They are mostly used for safety and also called as impact operators.

Based on velocity, they ae classified as Type-1 and Type-2.

- Type-1: They are less unstable and ignite more gradually.
- Type-2: They are more unstable and had high degree of rapid burn rate.

A. Blast Phenomena:

TNT is an explosive material made of a synthetic compound, which is assumed to be used in the current study to generate a blast. Impact is wave spreading out from blast. Impact arises because of fast arrival of energy of impact waves like rapid change of the state from fluid to gas or blasting pressure vessel from which compacted air develops. According to the US Department of Army, blast loading on structures is divided into two categories based on the confinement of explosive charge. They are: unconfined explosions and confined explosions.

The parameters that require attention in case of blast effects on building are:

1) Standoff separation and height
2) Magnitude of blast
3) Orientation of structure with respect to explosive and ground.
4) Geometry of the building structural framework

B. Blast Wave Interactions:

The intensity of the blast loading depends on the two criteria that are chosen to evaluate the effects of blast load on the structure: charge weight and standoff distances.

The three main classes of blast wave are:

1. The first-class blast wave is a wave generated from large scale impact and a target structure wherein the structure will be engulfed and crushed by the impact wave.
2. The second-class blast wave is generated in a small structure that is exposed to a huge impact. Ex: A vehicle. The targeted structure will be engulfed and crushed immediately resulting a translational power due to dynamic or drag loading will happen for long duration.
3. The third class blast wave is generated in large structures that are attacked by small scale blasts. Loading is done sequentially for a structure. The results obtained are analyzed separately for each individual element.

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II. LITERATURE SURVEY

A. Alexander Remennikov

His paper entitled "A Review of Methods for Predicting Bomb Blast Effects on Buildings" (2003) examines the way of blasts and the impact of blasts on structure.

B. J.M Dewey

His Journal of Physics entitled "The TNT Equivalence of Optimum Propane – Oxygen Mixture" (2005) explains that the impact waves delivered by the explosion of various sorts of explosives are generally contrasted and the impact wave created by a comparable mass of dynamite. He concentrated on the properties of the impact waves acquired from the molecule directions.

C. Mohammed S.L Ansari

In his examination work entitled "Building Reaction to Impact and Quake stacking" (2012) analyzes between the reaction of structures to impact and tremor loadings to determine a relationship in a type of formulae and graphs among seismic tremor and impact loads.

D. Prof. A.V. Kulkarni et.al

Their paper entitled "Examination of Impact Stacking Impact on Skyscraper Buildings" (2014) presents dynamic response of a tall structure exposed to effect load. The examination incorporates horizontal steadiness of an elevated structure demonstrated utilizing SAP2000 alongside essentials of impact dangers and connection of shoot waves with structures.

E. Sajal Verma et.al

In their diary entitled "Shoot Safe Plan of Structure" (2015) an endeavor is made to survey the different techniques connected to various kinds of structures like stone work, solid, steel and the adequacy of every strategy.

F. Zeynep Koccaz, Fatih Sutcu and Necdet Torunbalci

In their paper entitled "Compositional and Auxiliary Structure for Impact Resistant Structures" (2008) the target of the investigation leads on hypotheses of impact safe structure, redesign of structure protection from the effects of explosives in both building and basic structure procedure and plan frameworks that should be finished. This paper gives a brief clarification on explosives and blast sorts.

III. OBJECTIVE AND SCOPE

A. Objective

This project is regarding the behavior of tall buildings under the blast loads. The fundamental point of this examination can be abbreviated as continued.

1) To recognize the impact effects of explosives on tall structures.
2) Modelling and examination of tall buildings for air impact blast.
3) Analytical and numerical demonstration of influence of impact on tall buildings.
4) Evaluation of results from the investigation.

B. Scope

In the present study, a structure is designed understand its behavior when exposed to blast loads. ATBLAST software and TM5-1300 manual are used to obtain the blast loads. TNT is used in this study to examine the effect of that the different criteria, charge weight and standoff distances have on this structure. This study is mainly focused on the effect of impact load on the central bay along face 1 for each of the models.

C. Methodology

1. TM5 1300 manual is used to determine air blast pressure and impulse.
2. ATBLAST software is then utilized to calculate the blast loads.
3. Analysis of the structure subjected to blast load is finally done in ETABS.

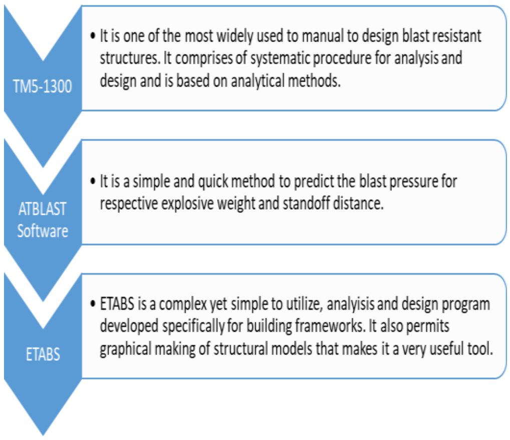

Figure1: Flowchart showing methodology of the study

IV. PROJECT DETAILS

The structure considered is a 10-story building with each story being 3m high. Base dimension of the structure is 17.25m X 20.49m. A plan is shown in Fig 2.

The sizes of the structural components are:

- Pillar: 230mm X 450mm
- Segment: 230 X 600mm
- Section: 100mm, 125mm, 150mm and 175mm
- Divider: 230mm

A. Input

- ATBLAST software and TM5 – 1300 manual are used to calculate the blast loads.
- Charge weight and standoff distance are the two criteria which influence blast loading.
- Two different charge weights of 700 and 1400lbs TNT and two different standoff distances of 5m and 10m are used to understand the effects.

B. Blast Analysis

Charge weight and standoff distances have a very huge impact on the results of this paper.

Following eight different buildings models are used in this study:

- **MODEL 1:** This model is subjected to charge weight of 700lbs and 5m standoff distance from **regular frame building.**
- **MODEL 2:** This model is subjected to charge weight of 700lbs and 10m standoff distance from **regular frame building.**
- **MODEL 3:** This model is subjected to charge weight of 1400lbs and 5m standoff distance from **regular frame building.**
- **MODEL 4:** This model is subjected to charge weight of 1400lbs and 10m standoff distance from **regular frame building.**
- **MODEL 5:** This model is subjected to charge weight of 700lbs and 5m standoff distance from **irregular frame building.**
- **MODEL 6:** This model is subjected to charge weight of 700lbs and 10m standoff distance from **irregular frame building.**
- **MODEL 7:** This model is subjected to charge weight of 1400lbs and 5m standoff distance from **irregular frame building.**
- **MODEL 8:** This model is subjected to charge weight of 1400lbs and 10m standoff distance from **irregular frame building.**

C. Loading

Gravity loads:

The loads considered are self-load, floor finish and live load as per IS 875(part 2):1987.

Seismic load:

Seismic load calculations are done as per IS 1893:2002. Following values are used as input:

- Seismic zone factor, Z = 0.1
- Response reduction factor, R= 3
- Importance factor, I = 1
- Soil type = II

D. Blast Loads

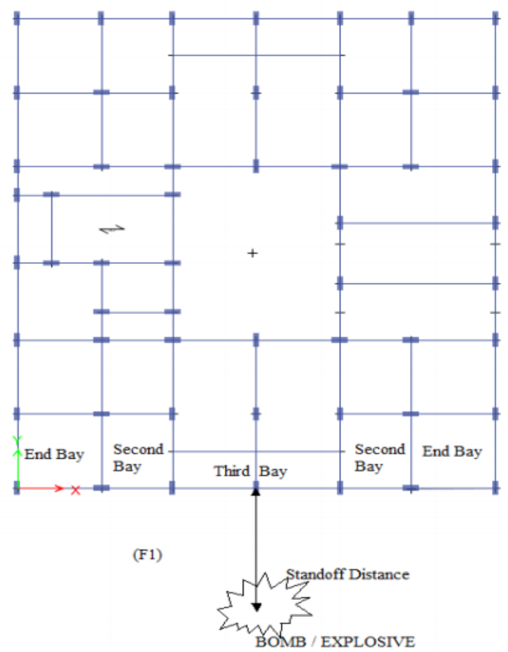

Figure 2: Typical location of the bomb or explosive along Face 1 (F1)

From ATBLAST software and TM5-1300 manual calculation, the blast load values are almost the same. Next, these values are further substituted for simplifying the analysis using ETABS software. From the point of impact, the variation of pressure with respect to the standoff length is thus calculated.

Table 1, 2, 3 and 4 clearly depict the impact of blast load on Central bay for each model that is considered. The ATBLAST software was used to obtain these results. From the tables, it can be easily noted that, resulting pressure due to the blast load is severe when the structure is closer to the explosion. Also, it is useful to note that pressure doesn't vary at longer distances. This, thus leads to very sever structural damage.

Table 1: Impact load parameters of Central Bay for Model 1 & Model 5

Storey level	Central Bay			
	Arrival Time (Ta) (ms)	Duration Of Load (Td) (ms)	Impact Pressure (Psi)	Impact Load (kN)
1	2.69	1.29	1298.07	167157.80
2	4	1.56	630.49	81190.78
3	6.37	3.56	178.27	22956.56
4	9.78	6.24	73.68	9488.08
5	14.1	8.05	44.96	5789.68
6	19.21	9.15	32.83	4227.65
7	24.97	10.27	25.16	3239.96
8	31.24	11.51	19.78	2547.15
9	37.94	12.65	16.12	2075.84
10	44.97	13.02	14.2	1828.59

Table 2: Impact load parameters of Central Bay for Model 3 & Model 7

Storey level	Central Bay			
	Arrival Time (Ta) (ms)	Duration Of Load (Td) (ms)	Impact Impact (Psi)	Blast Load (kN)
1	2.26	1.25	2245.89	289212.46
2	3.31	1.25	1222.25	157394.14
3	5.22	2.73	372.38	47952.90
4	7.99	4.82	153.42	19756.52
5	11.56	7.3	79.23	10202.77
6	15.85	9.4	50.67	6524.98
7	20.8	10.91	37.29	4801.99
8	26.29	12.01	29.72	3827.17
9	32.27	13.21	24.13	3107.32
10	38.65	14.44	20	2575.48

Table 3: Impact load parameters of Central Bay for Model 2 & Model 6

Storey level	Central Bay			
	Arrival Time (Ta) (ms)	Duration Of Load (Td) (ms)	Impact pressure (Psi)	Impact Load (kN)
1	7.28	3.02	310.85	40029.43
2	8.55	3.42	223.75	28813.20
3	10.84	3.78	155.59	20035.96
4	14.1	6.43	70.96	9137.81
5	18.23	8.05	45.6	5872.10
6	23.14	9.19	33.29	4286.89
7	28.67	10.31	25.48	3281.16
8	34.71	11.52	20.03	2579.35
9	41.2	12.12	16.99	2187.87
10	48.01	12.45	14.97	1927.75

Table 4: Impact load parameters of Central Bay for Model 4 & Model 8

Storey level	Central Bay			
	Arrival Time (Ta) (ms)	Duration Of Load (Td) (ms)	Impact Pressure (Psi)	Impact Load (kN)
1	5.96	2.57	617.49	79516.72
2	6.98	2.87	445.69	57393.33
3	8.86	3.17	305.61	39354.65
4	11.56	5.7	130.43	16796.01
5	15.02	8.01	73.77	9499.67
6	19.22	10.06	48.47	6241.68
7	24.03	11.02	37.74	4859.93
8	29.38	12.19	29.8	3837.47
9	35.21	13.38	24.18	3113.76
10	41.43	14.48	20.17	2597.37

V. RESULTS AND DISCUSSION

A. Results

Behaviour of any structure is based on many factors and hence evaluation of blast performance is a tedious task. In this paper, the models have been subjected to dynamic loads and then analysis is performed on them. After the analysis, results are depicted as graphs to understand the effect of the blast loads on tall structures.

Models are analysed with respect to the following criteria:

- **Story shear v/s story level**

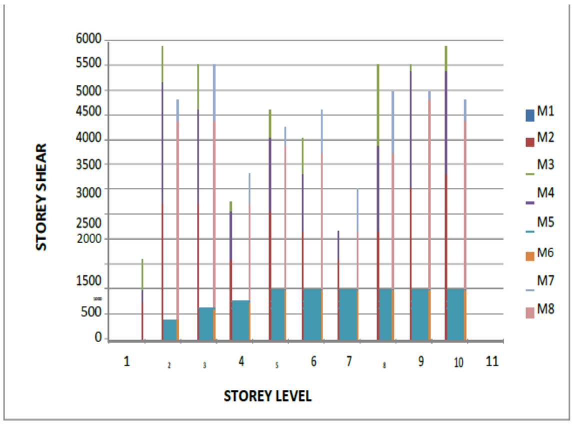

Chart 1: Story shear v/s story level

Table 5: Story shear v/s story level

Storey Level	Storey Shear							
	M1	M2	M3	M4	M5	M6	M7	M8
10	100.85	1074.77	3102.80	1954.07	1494.92	1281.73	2542.89	1706.65
9	277.80	854.79	1985.73	1687.01	1171.06	1204.12	1866.19	1797.43
8	445.25	1549.77	2439.98	2521.19	1739.40	1676.79	2812.87	2581.97
7	601.71	2089.43	4164.67	3541.19	2298.55	2219.52	3746.88	3224.06
6	744.58	1412.79	2913.40	2430.51	1588.88	1281.45	2650.85	2147.65
5	869.52	1250.50	2099.93	2044.25	1598.07	1542.65	2588.30	2322.76
4	969.65	1645.61	3089.31	2811.61	1599.73	1513.51	2598.92	2311.23
3	1037.12	1939.33	4503.69	3366.57	2452.49	2442.90	4066.80	3198.52
2	1067.12	1821.58	3598.67	3104.58	2137.17	1961.95	3491.37	3003.20
1	1037.30	2495.73	4881.87	4287.55	2685.57	2422.13	4415.03	3689.32
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

- **Story level v/s story displacement**

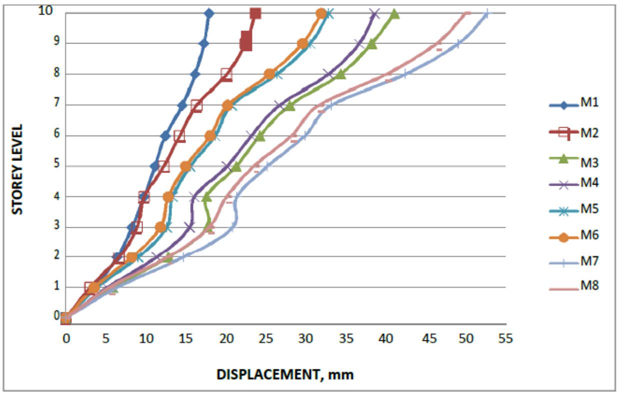

Chart 2: Story level v/s story displacement

Table 6: Story level v/s story displacement

Storey Level	Storey Displacement							
	M1	M2	M3	M4	M5	M6	M7	M8
10	17.896	23.705	41.056	38.628	32.849	31.922	52.739	49.971
9	17.269	22.47	38.221	36.677	30.548	29.596	49.081	46.349
8	16.174	20.112	34.361	32.867	26.416	25.472	42.459	40.072
7	14.564	16.372	28.009	26.721	20.715	20.24	33.193	31.623
6	12.472	14.233	24.263	23.191	18.675	18.055	29.902	28.22
5	11.151	12.256	21.3	20.152	15.546	14.976	25.212	23.524
4	9.794	9.806	17.565	16.083	13.363	12.824	21.392	20.088
3	8.261	8.903	17.703	15.479	12.621	11.835	20.865	17.896
2	6.438	6.676	12.821	11.354	9.031	8.275	14.736	12.742
1	3.617	3.024	5.889	5.176	3.898	3.54	6.388	5.412
0	0	0	0	0	0	0	0	0

- **Storey level v/s inter storey drift**

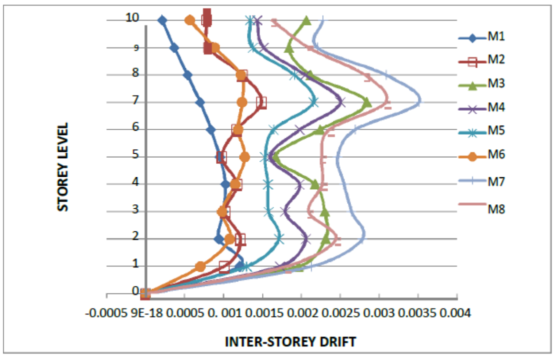

Chart 3: Story level v/s inter storey drift

Table 7: Story level v/s inter storey drift

Storey Level	Inter-Storey Drift							
	M1	M2	M3	M4	M5	M6	M7	M8
10	0.000209	0.000783	0.00206	0.001432	0.001342	0.000568	0.002279	0.00162
9	0.000365	0.000809	0.001839	0.001518	0.001377	0.000883	0.002207	0.002092
8	0.000537	0.001247	0.002117	0.002049	0.00191	0.001223	0.003089	0.002816
7	0.000697	0.001488	0.002839	0.002503	0.002156	0.001238	0.003513	0.003082
6	0.000839	0.001166	0.002239	0.00198	0.001644	0.001187	0.002693	0.00236
5	0.000953	0.000979	0.001665	0.001599	0.001532	0.001273	0.002466	0.002261
4	0.001024	0.001171	0.002176	0.001977	0.001571	0.001147	0.002549	0.002268
3	0.000994	0.001018	0.0023	0.001792	0.00158	0.000982	0.002645	0.002093
2	0.00094	0.001217	0.002311	0.002059	0.001711	0.001078	0.002783	0.002444
1	0.001206	0.001008	0.001963	0.001725	0.001299	0.000703	0.002129	0.001804
0	0	0	0	0	0	0	0	0

- **Joint Acceleration**

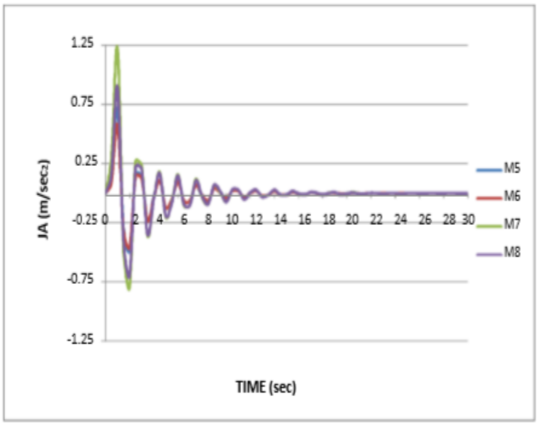

Chart 4: Joint acceleration

B. Discussions

- **Storey shear:**

The greatest storey shear is observed for Model 3 at all storey levels except at fourth and fifth level. At these two levels, the most extreme shear is observed for Model 7.

Least estimations of story shear are noted for Model 6.

- **Storey displacement:**

Most extreme story displacement is seen at tenth story level for Model 7.

Least story displacement is seen at first story level for Model 2.

- **Inter-Storey drift**

Highest Inter - Story drift is seen for Model 7 at seventh story level.

VI. CONCLUSION

A. Figures and Tables

- From the results obtained, the frame considered can be analysed by altering the parameters namely, control weight and the standoff separation distances. The results obtained can be altered by varying the above criteria.
- From graphical portrayal of impact weight, it can be observed that with increment in story levels, impact weight decreases, i.e., if blast occurs at lower story level, the impact weights are found to be high.

The following results are clear from the graphs and tabular columns:

- Model 7 has the highest storey shear at levels four and five.
- Most extreme storey displacement is seen at tenth story level for Model 7, i.e., 52.739 mm.
- Also, highest Inter - Story drift is seen for Model 7 at seventh story level, i.e., 0.003513 m.

Hence, from the above results, we can conclude that irregular frame with high charge weight(1400lbs) at the lesser standoff distance(5m) is the most susceptible to damage due to last loads i.e., Model 7. The application of this research can be done in designing a cost-effective structure which is resistant to blast loads.

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