BLAST RESISTANT BUILDINGS

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Abstract - *The enhancement in the number of terrorist attacks in the most recent years has exposed that the effects of Blast loads on a structure is an essential aspect to be taken into account during the design process. Even though such kind of attacks are very scarce in nature, blast effects must be considered while designing a building just like wind loads & Seismic loads. The main intent of this journal is to through light on the design of blast resistant buildings and to know the response of a structure when subjected to blast loads using ETABS software with prominence given on different Standoff distances of the blast and incorporating various charge weights of TNT according to the IS CODE 4991. Based on the needs and function of the building, dead loads, live loads & partition Wall loads are considered in the analysis of the building in accordance with the specifications of IS 875-1987.*

***Key Words*:** **DENOTATION CHARGE WEIGHT(TNT), STANDOFF DISTANCE, FRONT FACE PRESSURE, SIDE FACE PRESSURE, NUMBER OF COLUMNS/BEAMS FAILED, BEAM AND COLUMN DIMENSIONS REQUIRED FOR BLAST RESISTANT BUILDINGS, ETABS.**

1.INTRODUCTION

The terrorist attacks on buildings has become an emerging issue in the current world. Hence providing security to the residents of the building against terrorist attacks is gaining importance day by day. It includes prediction, prevention & lessening of such acts. If the risk of terrorist attacks cannot be prevented; at least loss of life , damage to the property & public fear are the key aspects that is to be lessened. Designing a structure to be absolute resistant to blast is not an economical choice of approach. Hence with the knowledge of modern architectural and engineering experiences designing a building to be blast resistant within considerable limits will be unquestionable.

To analyze a building for blast loads there is a need of exceptional understanding of the phenomenon of the blast occurrence and the analysis of the response obtained by the structural elements. The various steps involved in the analysis of the blast loads applied on a building are as follows- i) Judging the threat involved. ii) Assessment of the computational loads that is to be considered anticipating the hazard that may arise. iii) Choosing a specific Structural system like space truss, diagrid, tubed frame etc. iv) Study of the structural performance of the structure subjected to blast loadings. v) Assessment of the behavior of the building when subjected to blast loads.

1.1 OBJECTIVES OF THE WORK

a)The motto of the study is to shed light on designing of buildings which can resist blast attacks & increasing the safety of the structures. b) For getting an idea of blast progression & to understand the effects of blast on structures. c) For judging the chances of occurrence of an explosion in the lifetime of a building & the impact factor that is to be considered based on the importance of the structure. d) For knowing the response of a building when subjected to blast loadings using ETABS software as per IS Code 4991. e) To know the response of a structure when subjected to blast loads of different standoff distances & various charge weights. f) To draw a conclusion of the ideal amount of safety that is to be considered in the design for making a structure economical.

2 BLAST PHENOMENON & EXPLOSIONS

Explosions are classified based on their nature as nuclear blasts, physical blasts & chemical blasts. In nuclear explosions the energy will be released as a result of the reactions developed because of the formation of unlike atomic nuclei formed by the rearrangement of the protons & neutrons in the interacting nuclei. Physical explosion is a result of mixing highly reactive liquids, setting ablaze of explosive materials, exploding of gas cylinders etc. Chemical explosion is a result of quick oxidation of fuels mainly which consists of carbon & hydrogen atoms.

2.1 BLAST LOADING ON BUILDINGS

The damage that a bomb can cause mainly depends on two aspects 1) Charge weight (W) in Kgs of TNT 2) Standoff distance between the blast source & the building. The major threat to a structure is that of a immobile vehicle weapon located in the vicinity of the structure. The Fig-1 shows the Vehicle weapon blast with standoff distance & blast pressures mentioned in it. It also shows the perimeter protection area that is to be maintained. The type of the expansion of the blast wave from the source of the blast to the building is shown in the figure. The magnitude of the weapon considered in the form of vehicle may vary from hundreds to thousands of kgs of TNT & it is considered based on the importance of the building to be constructed.

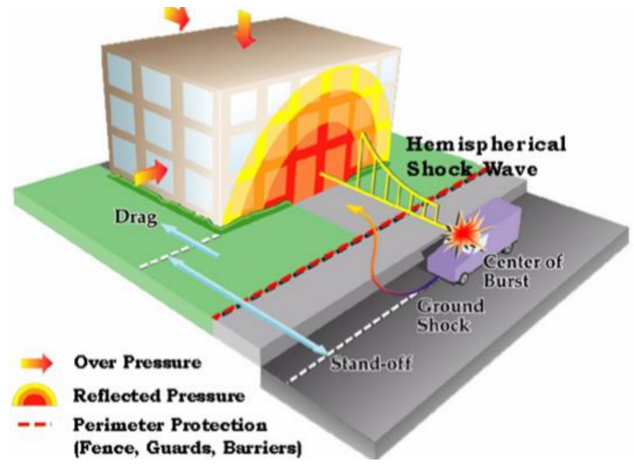


Fig-1 Vehicle weapon blast

It is not possible to declare that blast shall happen in only one direction. Hence safety precautions should be taken from all directions. The highly affected beams & columns because of a blast are that of the basement region. So they are to be strengthened. A feasible way to protect the structure is by providing barrier compound all round the structure. The process of expansion of blast wave includes the phase of breaking up of windows, exterior wall columns, lifting up of floors, downward pressure on roof etc.

3 MODELLING & ANALYSIS

The various steps followed in the project are listed below
A)Model Generation: The building is modeled using ETABS software with following specifications 1)Dimensions-16mx14m with 4 bays of 4 meters & 4 bays of 3.5m respectively. 2) Total height of the building 18m with floor height 3m & footing level 1.5m below GL. 3) Initial column & beam dimensions provided without blast load was 400mmx400mm & 300mmx400mm respectively.

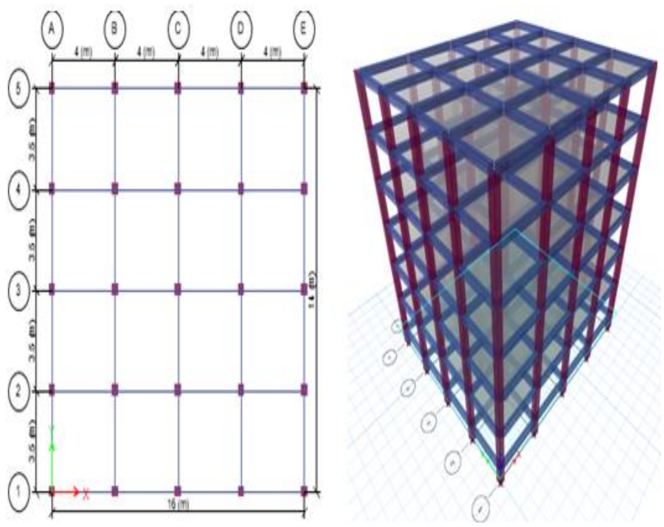


Fig-2 Plan & 3D Model of the building

B)Load Calculations: Live load of 2kN/m^2 was applied on the slab of 150mm thick & Wall load-13.22kN/m was applied on beams. The Blast loads were calculated as per I.S code 4991 for 16 different cases which is mentioned in Table-1. The magnitude of the blast pressure calculated is applied as an UDL on Column & Beams.

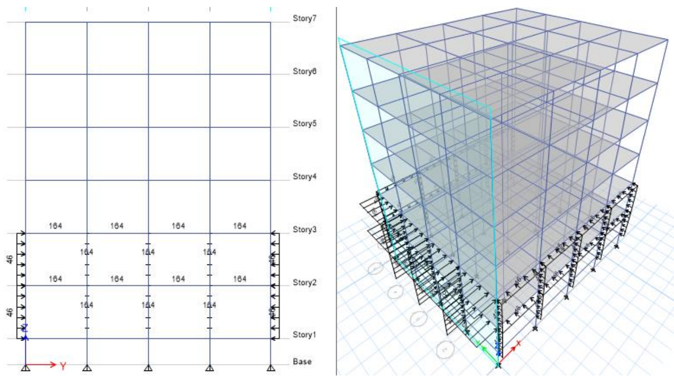


Fig-3 Blast load applied on the Front & Side face of building

C) Analysis: Characteristic strength of Concrete & Steel provided was fck- 25N/mm^2 & fy-550 mm^2 respectively. Load combinations: 1) 0.9DL+1BL 2)1.2DL+1.2BL+1BL 3) 1.5DL+1.5LL 4) 1.5DL+1BL. The model is checked for correctness & analyzed. The number of beams & columns failed because of blast load in that particular case is noted. The dimensions of the failed beams and columns are increased & the area of steel is also enhanced until it pass the analysis for the applied blast load.

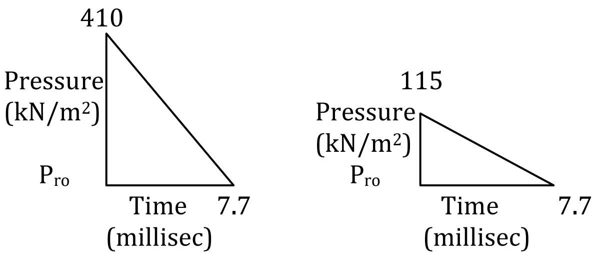
3.1 CALCULATIONS

The calculations of Case-1 for 125kgs/0.125tonne TNT charge weight & standoff distance of 15m is shown below. Height of the Structure-19.5m, Length-16m, Width-14m

i)Characteristics of blast-
Scaled distance x = $15/(0.125)^{1/3}$ =30m.
From Table 1 of I.S code 4991:1968 P_a=1 kg/cm^2 & for scaled distance of 30m the Pressures are P_{so}=1.4kg/cm^2, P_{ro}=4.2kg/cm^2, q_o=0.58kg/cm^2
The scaled times t_o and t_d obtained from Table 1 for scaled distance of 30m are multiplied by $(0.125)^{1/3}$ to get the values of actual explosion of 0.125 tonne charge.
$t_o=22.93x(0.125)^{1/3}$=11.47milliseconds.
$t_d=15.39x(0.125)^{1/3}$=7.7milliseconds. U= M x a
M=Sqrt(1+6P_{so}/7P_a) =Sqrt(1+6x1.4/7)=1.48
a=344m/s(Velocity of sound in air at mean sea level)
U=1.48x344=509m/millisecond.

ii) Pressure on the Building
H=19.5m, B=14m,L=16m S=H or B/2
whichever is less=19.5 & 14/2=7 so S=7m
t_c=3s/U=(3x7)/0.509=41.26 milliseconds
t_t=L/U=16/0.509=31.43 milliseconds

t_r=4s/U=(4x7)/0.509=55 milliseconds
t_r>t_d so, no pressure on the backface are considered.
For side face C_d=-0.4, P_{so}+$C_d q_o$=1.4+(-0.4)x0.58=1.17kg/cm^2
Conversion from Kg/cm^2 to KN/m^2
=4.2Kg/cm^2=4.2x9.81N/cm^2=(41N)/(10^{-4}m^2)=410KN/m^2
The pressure diagrams are as shown below:



In the same way the blast pressures are calculated to all the 16 cases as mentioned in the Table- 1 & 2 by varying standoff distance & charge weight.
Initial specifications provided prior to the application of Blast loads on the structure are-
Grade of concrete-M25, Grade of Steel-Fe 550
Dimensions of Columns provided initially- 400mmx400mm
Dimensions of Beams provided initially- 300mmx400mm
Area of steel provided for middle column of Non-Blast building is 1280mm^2
Grade of concrete provided for blast resistant or failed beams/columns is M30.
The front face pressure & side face pressure are applied as an uniformly distributed load to the beams & columns by multiplying the width of the beam or column with the blast pressures. The number of columns and beams that have failed to resist the applied blast loads are noted & the dimensions of those beams & columns are increased along with the increasing of the area of steel. The obtained column & beam dimensions & area of steel required to resist the applied blast loads are tabulated below.

Table -1: Details of the result obtained.

Case No	Denotation Charge Weight (TNT in Kgs)	Stand off Distance (m)	Front face Pressure (kN/m²)	Side face Pressure (kN/m²)	Maximum Joint Displacement (Top Storey) in mm
1	125	15	410	115	72.8
2	125	20	214	73	46.5
3	125	25	132	50	35.3
4	125	30	91	37	28.7
5	250	15	859	179	186.1
6	250	20	369	108	80.1
7	250	25	216	74	46.6
8	250	30	146	54	30.9
9	375	15	1330	250	236.1
10	375	20	533	134	94.5
11	375	25	299	93	53.3
12	375	30	169	69	34.6
13	500	15	1926	353	416.5
14	500	20	727	162	129.2
15	500	25	376	108	66.6
16	500	30	242	79	43.1

Table -2: Dimensions & Area of steel of the blast resistant beams & columns

Case No	Number of Beams /Columns Failed	Column Dimensions required for Blast Resistant Buildings BxD(mm)	Beam Dimensions required for Blast resistant buildings BxD(mm)	Area of steel required for Blast resistant buildings for center column of blast load in mm²
1	85	500x500	350x500	4538
2	10	400x400	300x450	6716
3	0	400x400	300x400	1983
4	0	400x400	300x400	1428
5	141	700x700	450x800	9362
6	101	500x500	300x550	5563
7	10	400x400	300x450	6716
8	0	400x400	300x400	3259
9	164	850x850	500x900	9995
10	113	550x550	350x550	5302
11	47	450x450	300x450	4051
12	0	400x400	300x400	4210
13	177	1200x1200	750x950	12866
14	128	750x750	350x600	6588
15	72	500x500	300x500	3985
16	3	400x400	300x450	6308

The above obtained results are analyzed by plotting the following graphs;

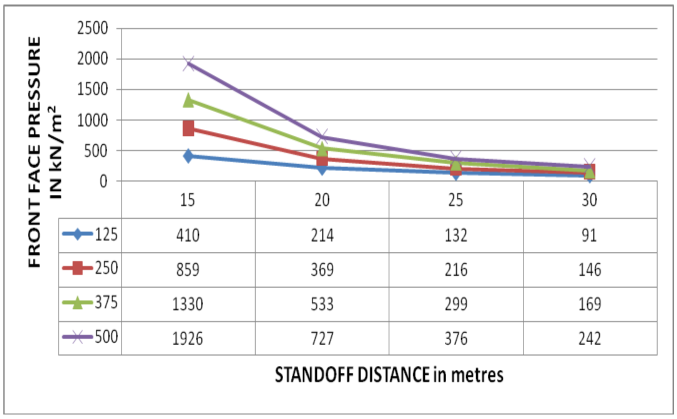
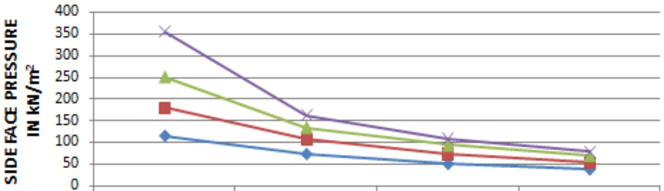
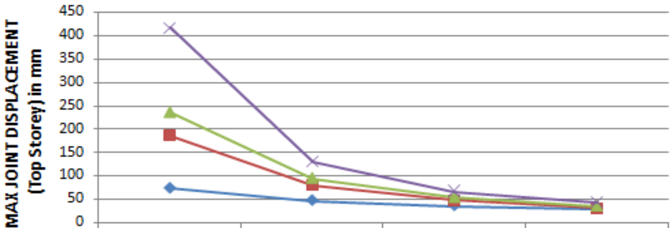


Chart -1: Front face pressure vs Standoff distance



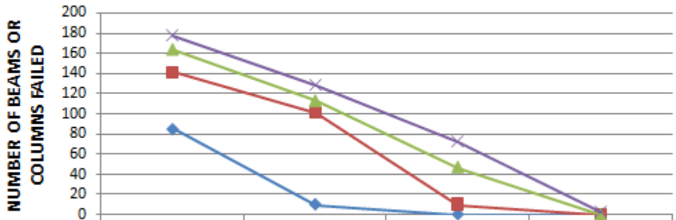
	15	20	25	30
125	115	73	50	37
250	179	108	74	54
375	250	134	93	69
500	353	162	108	79

Chart -2: Side face pressure vs Standoff distance



	15	20	25	30
125	72.8	46.5	35.3	28.7
250	186.1	80.1	46.6	30.9
375	236.1	94.5	53.3	34.6
500	416.5	129.2	66.6	43.1

Chart -3: Max Joint displacement vs Standoff distance



	15	20	25	30
125	85	10	0	0
250	141	101	10	0
375	164	113	47	0
500	177	128	72	3

Chart -4: Number of Beams or columns failed vs Standoff distance

All these graphs clearly depicts the importance of providing standoff distance to the buildings during an occurrence of blast. It can be noted that at a distance of 30 meters standoff distance the number of beams & columns that have failed are just 3 beams though the occurrence of blast was of charge weight 500kgs & no beams have failed for 125,250 & 375 kgs charge weight. So it is very important to provide an effective standoff distance for the safety of the structure.

3 CONCLUSION

The following conclusions were drawn from the results obtained from the analysis of the study.

1) Important buildings like Embassies, banks, hospitals, monumental buildings, head quarters, historical buildings, government buildings, federal buildings etc should be designed & analyzed to withstand blast effect within acceptable limits.

2) The G+5 storey RCC structure when subjected to blast loads generated by the charge weight of 125kgs with standoff distance of 30 meters hardly had any effect on the structure, but when the same building when subjected to blast loads developed by 500kgs with standoff distance 15 meters the count of beams & columns that failed was 177.In this case the performance of the structure is very critical.

3) Though there are guidelines available for the design of buildings to be blast resistant, those guidelines are very rarely used in designing the conventional structures. Hence by considering such guidelines the buildings are to designed more robust in nature.

4) It was found that the most ideal model to resist the blast effect is a regular symmetrical frame because they are least prone to damage & exhibit great strength when compared to that of irregular buildings.

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