Analysis of RC Multistory Building With And Without Blast Forces

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Abstract: Blast resistant and anti-terrorism design is essential in order to save the civil infrastructure and human lives. In the design of structures, a consideration for energy absorbing capabilities to resist the effects of blast loading or other severe dynamic loads it is vital, and structural provision of elements with large plastic deformation capacities is desirable. Structures need to be designed for ductile response in order to prevent partial or total collapse due to locally failed elements. The work in this paper considers theoretical studies to resist the structure against blast loading to understand the basic concept of explosion phenomena, parameters of blast loading, and different types of blast waves. The analysis focuses on the estimation of blast loading on structures and their response to explosions. Design of blast resistant structures requires thorough understanding of the structural dynamics, behaviour of materials under high strain rate of loading, and blast analysis. This paper concludes with an explanation of findings by different researchers using different country codes to simplify the design process for calculating blast load.

Keywords: Blast Resistant Design, Blast Load, Explosion, ETABS.

INTRODUCTION

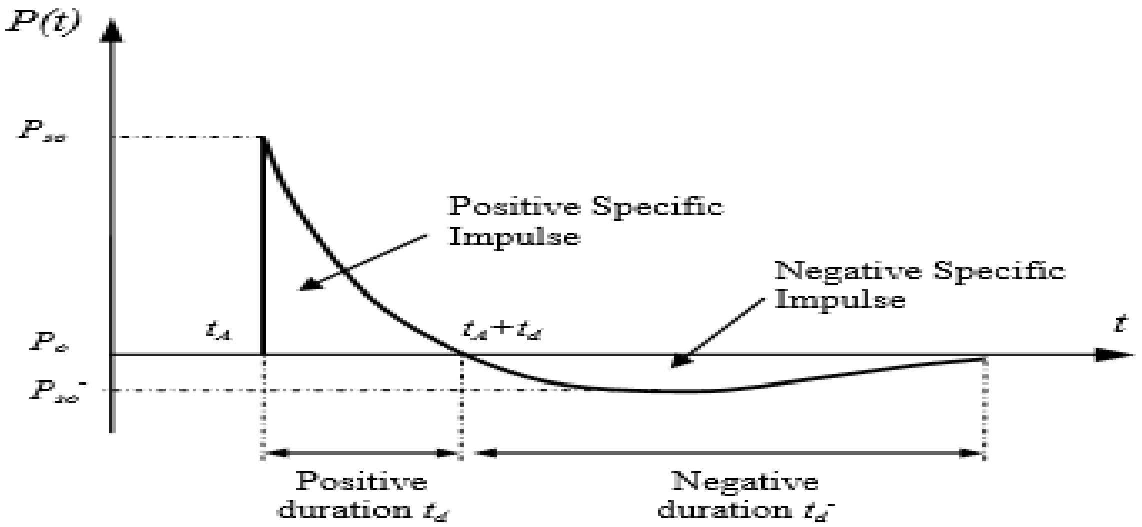
A blast is a harmful wave of well-compressed air extending outwards from explosives. Blast load is the load applied to a structure from a blast wave that comes immediately after an explosion. The blast-resistant design has become an important part of the design for important structures because of hazards due to extensive terrorist activities in various parts of the world. Design must be such that it may adapt the protection to lives and buildings. Loss of life and injuries to occupants can result from any causes, including direct blast effects, structural collapse, and impact of debris. One of the factors typically considered in designing safer buildings and structures is their ability to prevent total collapse after the loss of load-carrying components resulting from blast loads.

Disasters such as Manchester Arena bombing, UK, 22nd May 2017, at the Ariana Grande's pop concert, Baghdad Bombing, Iraq, 3rd July 2016, terrorist bombings of the 13th November 2015 Paris attacks were a series of coordinated terrorist attacks in Paris and its northern Suburb, Mumbai 26/11 terrorist attack and many more have demonstrated the need for a thorough examination of the structures subjected to blast loads. With the present knowledge and software, it is possible to perform analysis of structures exposed to blast loads and to evaluate their response. Blast loading or impulse loading is a type of load acting for a very short duration of time. Graphically, blast loading is drawn as a triangle, referring as triangular loading.

Blast Wave Profile

A shock wave is generated in the air which moves outward in all directions. The shock wave consists of an initial positive pressure phase followed by a negative phase at any point. Peak positive intensity quickly drops down to zero, the maximum negative overpressure is much smaller than the peak positive overpressure its limiting value being one atmosphere. But the negative phase duration is 2 to 5 times the positive phase.

The negative phase is longer than the positive phase and its minimum pressure value is denoted as P_{so} and its duration as t_o in this phase the structures are subjected to suction forces. The negative phase of the wave is usually not taken into account for design purposes as the main structural damage is connected to the positive phase.



pressure vs time graph

Blast load: Type of blast load on the basis of confinement of explosive charge.

1. Unconfined explosive

An explosion that occurs in the air or near the surface is considered an unconfined explosion. Unconfined explosive is divided into three types

- Air blast: An explosive charge is detonated off in the air, the blast waves spread spherically, interact with the ground before hitting the structure.
- Free air blast: The explosive charge explodes in the air, the blast waves spread spherically, and they strike the structure directly, without first interacting with any other objects or the ground.

- Surface blast: The explosive charge is detonated almost at the ground surface, the blast waves immediately interact locally with the ground and they next propagate hemispherically outwards and impinge onto the structure.

2. Confined explosive

The explosion that occurs inside the building is considered the confined explosion

Confined explosive is divided into three types

- Fully vented: the explosive charge is detonated in a closed container having fully space or vented in space they do not provide any proper shape.
- Partially vented: The explosive charge is detonated in the close container having partially space or vented in space.
- Fully confined explosion: The explosive charge is detonated in the close container. In this case volume is considered as constant. Ex- explosion occurs within building.

Numerical Model Specification
General Specification (G+4)
Occupancy classification- office Building.

Ground + 3 Stories + Terrace Floor

Dimensions of Building
Length- 48m
Width- 48m
Height- 16.25m
Each floor height- 3.25m

Material Specification
• Grade of Concrete: M40

• Grade of steel- HYSD415- For shear Reinforcement

• Grade of steel- HYSD500- For longitudinal Reinforcement

For G+4 Story structure

- Size of column (C1) - 450×700 mm (All inner columns and outer columns after second floor)
- Size of column (C2) - 450×800 mm (outer columns up to second floor)
- Size of beam - 450×700 mm

For G+9 Story structure

- Size of column (C1) - 550×850 mm (All inner columns and outer columns after third floor)
- Size of column (C2) - 650×1050 mm (outer columns up to third floor)
- Size of beam - 650×850 mm

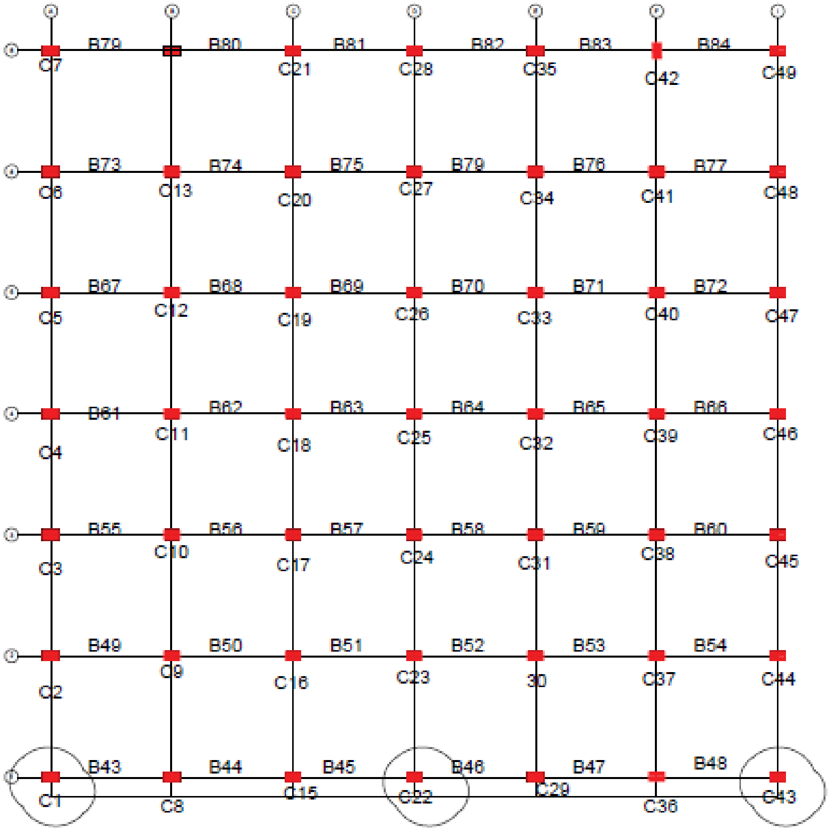
Cases considered for design

- Case 1: blast of 100kg explosive with standoff distance of 30m (as per IS 4991:1968 Table 7)
- Case 2: blast of 100kg explosive with standoff distance of 60m

- Case 3: blast of 100kg explosive with standoff distance of 100m
- Case 4: blast of 200kg explosive with standoff distance of 30m
- Case 5: blast of 200kg explosive with standoff distance of 60m
- Case 6: blast of 200kg explosive with standoff distance of 100m

Single column removal case one at a time studied. And load combination is (DL+LL+BL)

- For Case 1,2,3 – C1,C22,C43(G+4 Story Building) (As per GSA Guidelines)
- For Case 4,5,6 – C7,C10,C13(G+9 Story Building)



plan view

OBJECTIVE OF STUDY

- To understand the explosion process and to have a clear idea about the effects of the explosion on buildings.
- Analysis of blast-resistant G+4 and G+9 RC buildings with normal gravity load + Lateral load without blast load.
- Analysis of blast-resistant G+4 and G+9 RC buildings with normal gravity load + Lateral load also with blast load.
- To know the response of a structure when a building is subjected to blast loads using ETABS software with IS Code 4991:1968.

REVIEW OF LITERATURE:

Research paper from different journals is concentrated to compare the significance and need of this examination with regards to the design of structure to resist blast forces. Following surveys gives an idea about behavior of structure when it is subjected to blast load.

Kratz et al. (2001): studied the structural failure of a reinforced concrete building caused by the blast load and the process of the explosive charge to the complete demolition, including the propagation of the blast wave and its interaction with the structure was reproduced. They have grouped the structures which need blast design considerations into three classes and a fourth class for which the "normal" design requirements deem to satisfy any blast design requirements. They carried out the analysis with an equivalent static method.
Remark: They have briefly explained the process of the explosive charge and propagation of blast waves.

Pedro Silva et al. (2009): studied the basic procedure to estimate the explosive charge weight and stand-off distance to impose certain levels of damage on RC structure. Different experiments were also conducted to confirm its applicability for assessing the blast resistance capacity of RC slab. They consider a one-way square RC slab; it is tested under real blast load by changing the stand-off distance al explain the DBD method to estimate the damage level. Based on the experimental result the slab has demonstrated that the achieved displacement ductility levels, damage level, and residual crack width matches the anticipated values well.
Remark: they have explained how to estimate the explosive charge weight and different stand-off distances.

Hrvoje Draganic et al. (2012): Explain the process of blast load, blast load is determined as a pressure time history and analysis is done in SAP2000 loading and blast parameters can be determined by Eurocode (EN 1991-1-7). It was necessary to analyse the loading for each point of the structure. The aim of the analysis of the structural elements exposed to blast load is to check their demanded ductility and compare it to the available ones. This means that non-linear analysis is necessary and simple plastic hinge behaviour is satisfactory.

Remark: explained the process to calculate the blast load by using Eurocode and the effects of explosives on the structure.

Dr.C.B.K.Rao et al.(2013): study illustrates the inherent ability of seismically designed RC beam-column frames to resist progressive collapse. In this paper, a six-storey building is considered and a simplified analysis is done by removing one column at a time as per GSA standard. Modifications to GSA clauses have been proposed by introducing dynamic increase factor for simplified analysis, to prevent the progressive collapse results of the analysis showed that increase 13% of total steel used in this structure, which is negligible to the total cost of the structure.
Remark: explained the processor of load path transfer when one of the structural elements fails and resist the structure against progressive collapse.

Progressive collapse behaviour of a beam-column structure in mid-column removal scenario was studied by **Yu and Tan (2013)** with both experimental and numerical approaches. The main parameter investigated by them is the effect of rotational and axial restraint boundary conditions. Engineer's Studio program was used to implement the finite element analysis of their component-based model. Though slab is not considered in their study, general requirement on boundary conditions for the development of compression arch action and catenary action were studied.

Suraj D Bhosale et al. (2016): studied the six story RCC building situated in zone IV and calculate the blast pressure parameters as per IS 1449:1968 with an 100kg explosive effects on structure. It is also analysed using STAAD-Pro software. The findings from the results are that the effect of peak static pressure and reflected overpressure was more at ground store then upper store varies linearly.

Remark: They explained the design procedure by using Indian standard code.

Zhen Liao et al. (2019): studied the explosion resistance performance of high strength reinforced concrete beams analyse the results on dynamic response of RC beam. Compare the results of high strength reinforced concrete beam and ordinary reinforced concrete beam with different blast loads. Damaged zone plot on P-I curve, curve represent peak overpressure and impulse of blast loading applied on the structure. The observations show that high strength reinforcement can significantly reduce component deformation as well as the length and width of cracks, improving the explosion resistance performance of RC beams under blast loads.

Remark: explained the behaviour of beam with respect of high strength RC beam and ordinary RC beam it is unique research with respect to other research papers.

Rishabh et al. (2019): studied the types of explosive and blast waves, compare the results of different types of blast waves i.e., free air bursts, air bursts, surface bursts with respect to the parameters of positive phase of shock wave. Model considered for analysis is an isolated structure situated at a stand-off distance of 22.5m with C_4 explosive. Also gives the graphs of effect of distance of blast for same explosive material on different surfaces of the structure and Effect of various explosives for the same stand-off distance on different surfaces of the building. From the results, they it is concluded that, with increase in distance, there

is significant decrease in the deformations in the building. Therefore, for close explosions additional reinforcement is needed, while for distant explosions, conventional reinforcement provides sufficient ductility.
Remark: explained the types and behaviour of blast waves briefly.

Ms. Shikalgar Sana Rafik (2022): studied a G+25 story RCC building by using ETABS software creating two types of models for analysis. One is G+25 with shear wall and second is G+25 with bracing. The main intent of this Study is to throw light on the design of blast resistant buildings and to know the response of a structure when subjected to blast loads utilizing ETABS software with prominence given on different Standoff distances of the blast and incorporating different charge weights of TNT according to the IS CODE 4991. This study examined the blast loads applied to buildings with shear walls and bracing.

Remark: They explained the behaviour of structure with and without bracing and shear all in simplest way. Depending upon the above studies my current study is to find out the behaviour of RCC structure, in front face, side face and rear face with different standoff distances. Behaviour of structure is observed in ETABS software and finally make structure to sustain blast loads.

Summary

From the reviewed literature, a clear idea has been developed in various aspects of theory and modelling of blast loading on structures. Also, it is understood that not much studies were conducted on ground blast loading on structures. The effects of blast explosions, behaviour of blast loads was studied so far. The effects of change in stand-off distance of blast, charge weight, change in grade of steel are the parameters and with and without shear wall, with bracing are cases to be studied for various load conditions including maximum and minimum axial load, maximum bending moment etc. in this project work. ETABS software is selected for the modelling and analytical purposes. Ground blast loading is applied on the structure with changing the stand-off distance. Direct shock effects along with ground shock effects are considered in the loading. The main aim in blast proof building design is to prevent the overall collapse of the building and damages.

Recommendations for Future Work

The following point can be considered of future scope: -

1. The models are designed with and without blast resistance by zone III and stand-off distance 30m. it can be extended by different seismic zone and stand-off distance.

2.All research find out the displacement, story drift, story shear to check behaviour after applying blast load. It can be extended by check the shear force bending moment and deflection.

3. Check the change in BM, SF and deflection at failure frame element and give proper solution to resist the structure.

4.most of the work is in ETABS and STAAD Pro software, other software like Ansys, Abaqus, LSDYNA can be use.

5. While providing accurate prediction of behaviour from blast loads the finite element analysis requires some expertise. Therefore, for the designer new to blast design, the use of SDOF manuals and programs may be the simpler and less time
consuming option.

6. While the ASCE publications provide guidance for blast design they are not design manuals therefore the most widely used is TM 5-1300.

CODE REVIEW

1. IS 4991:1968

IS 4991:1968 gives criteria for the design of structure for blast effects above the ground surface. They do not give criteria for design of blast effect of nuclear explosion.

- General characteristics of blast:
  - **Shock wave:** The shock wave has a positive pressure phase at the beginning, followed by an adverse pressure phase at any point. From the point of explosion, it is generated in the air and spreads in all directions.
  - **Pressure and duration:** The pressure rises almost to the peak values. The peak values depend on size of explosion, stand-off distance, ambient pressure and temperature. The maximum negative overpressure is much smaller than peak positive overpressure. The negative phase duration is 2-5 times long as that of positive phase overpressure. Therefore, negative phase duration considers as negligible only positive phase consider at the time of design & analysis.
  - **General principle:** longer the natural time period of member smaller the effective load for design. Lack of known orientation of future explosion, every face of structure shall be considered as a front face.
- Blast force: All blast parameters i.e., p_{so} positive side-on overpressure, p_{ro} reflected overpressure, q_o dynamic pressure, t_d equivalent triangular pressure are given in the Table 1 in IS 1449 by calculated scaled distance(x) all this parameters can be find out from table1.(IS 4991)
- **Blast load on above ground structures**:

  Type of structure

1) Diffraction type of structures: These structures are without openings in it. This type of structure subjected to both shock wave overpressure and dynamic pressure.
   Condition- when area of opening is less than 5% of area of wall than it is considered as diffraction type structure.
2) Drag type structure: These are open type structures. This type of structures is subjected dynamic pressure only.
   Condition- when the area of opening is more than 50% of area of walls, then it is considered as drag the structure.

- Design stress for structural steel

  Dynamic yield stress exceeds the minimum specified static yield stress by 25% and that of heigh strength alloy steel by 10%.
- Design stress for reinforced concrete

  Dynamic cube strength assumed to be 25% higher than minimum static cube strength.
- Design stress for masonry or plain concrete

  Compressive strength taken as 25% higher than the static strength.

2. Unified Facilities Criteria (UFC 4-023-03)

The Unified facilities criteria provides the design requirement to reduce the potential of progressive collapse for new and existing building. All buildings of three or stories are subjected to greater risk of progressive collapse, all building having two or more stories must be design with progressive collapse.

- **Design approaches**
- ➢ Direct design approaches: This includes explicit consideration of resistance to progressive collapse during design process by using alternate path method and specific local resistance method.
- ➢ Indirect design approaches: This includes resistance to progressive collapse implicitly through the provision of minimum level of strength, continuity and ductility.
- Requirement of progressive collapse design
- ➢ Tie forces- which gives tensile force strength of floor to allow the transfer of load from damaged portion to undamaged portion of structure.
- ➢ Alternate path method: which provides alternate path when one of the element removed.
- ➢ Enhanced local resistance: in which addition protection provided to column & wall to reduce extend of initial damage.

  In this code design process is explained on the basis of these three design approaches.

3. TM 5-1300 (structures to resist the effects of accidental explosions)

To establish design procedures & construction techniques whereby propagation of explosion and provide protection for a structure. Explain regarding expansion protection system. Gives criteria for the design of structure for blast effects based on fragment. This code can be used for flat, cylindrical and spherical surface.

All design parameters, type of structure, types of explosives is defined as per IS4991. They give general information regarding principle of dynamic analysis, reinforced concrete design, structural steel design etc.

4. ASCE (Design of blast-resistant buildings in petrochemical facilities)

Provides guidelines on the various methods available for the structure design of blast proof building in petrochemical & chemical process plant.

- Types of blast overpressure

1.High pressure- short duration – triangular shock loading – over pressure of 69 kpa with duration of 20 millisecond.

2.Low pressure- long duration – triangular shock loading – overpressure of 21 kpa with duration of 100 millisecond.

- ➢ Greater the spacing between buildings and an explosive source, lesser the overpressure but longer the duration of blast loading.
- Building blast loading

When blast wave strikes a building, the building is loaded by the overpressure and drag forces of the blast wave.

- ➢ Front wall loading: wall facing the explosion will experience a reflected overpressure. Reflected overpressure amplification of blast depends on angle of incidence, time and side-on overpressure.
- ➢ Side walls: The side walls experienced less blast loading than front wall. Peak side-on overpressure will not be applied uniformly varies with time and distance.
- ➢ Roof loading: roof experienced same loading as a sidewall. the dynamic wind forces on roof act in the opposite direction to the overpressure(upward)

- Leakage pressure: blast load applied to the building exterior and expand into the building through openings in the walls or roof. Methods available to compute pressure is given in UFC 3-340-02.

5.ASCE (370-R-14): Report for the design of concrete structure for blast effect)

This report addresses the design of structures to resist blast effects due to explosions also the steps commonly followed in this report, including determination of the threat, calculation of structural loads, behaviour of structural systems, design of structural elements, design of security windows, design of security doors, and design of utility openings.

- **General principles of structural design**

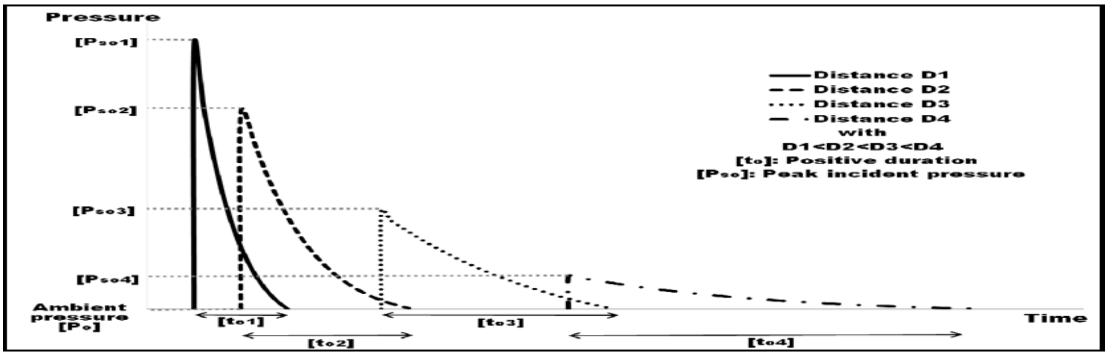
When a threat occurs, a structural system that activates reacts both locally and globally. The local response is characterised by penetration and local injury and may result from the direct impact of a fragment. The overall response, primarily brought on by blast overpressures, is the dynamic behaviour of the structural components and the entire structure.

The impact of openings on a building's overall load calculation. The mode of failure is also significant. There are two forms of window failures: window connection failure and glazing material failure. A connection failure is the failing that is most frequently seen with doors. For doors, a failure in serviceability is crucial.

- **Analytical methods**: Analytical methods have been developed to predict blast loads. These methods fall into two groups: semi-empirical and hydrocode.
- The semi-empirical approach uses a physics-based model to compute selected blast parameters with limited to configurations and charge weight ratios for which data are available.
- Hydrocodes use a grid of computational cells to track detonation propagation through an explosive charge.

Scaling laws

When two explosive charges with similar geometry and the same explosive but different sizes are detonated in the same atmosphere, self-similar blast waves are produced at the same scaled distance. According to Hopkinson-Cranz law, a dimensional scaled distance is introduced described by $Z=\frac{R}{\sqrt[3]{W}}$



Influence of distance on the blast positive pressure

Calculation of blast Forces for G+4 and G+9 story structure of standoff distance 30m

calculation of blast pressure for triangular time history nodal load as per IS 4991:1968

At Ground Floor (0m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	30	31.04	34	38.41
Scaled Distance	64.63	66.87	73.25	38.41
P_{so}	0.39	0.32	0.28	0.245
t_d	39	36.25	30.36	31.87
q_o	0.39	0.036	0.017	0.021
t_o	37.89	38.58	40	41.2
Pr_o	0.824	0.741	0.65	0.54
Loads on front face joints of the structure				
	1070	964	420	354

At First Floor (3.25m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	30.17	31.21	34.15	38.55
Scaled Distance	64.99	67.25	73.57	83.05
P_{so}	0.35	0.32	0.29	0.24
t_d	38.13	38.49	30.27	31.94
q_o	0.043	0.036	0.029	0.021
t_o	37.55	38.49	39.92	41.82
Pr_o	0.825	0.735	0.65	0.62
Loads on front face joints of the structure				
	1053	954	385	224

At Second Floor (6.5m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	30.69	31.72	34.61	38.96
Scaled Distance	66.11	68.34	74.57	83.94
P_{so}	0.32	0.33	0.29	0.24
t_d	29.3	28.96	29.99	31.94
q_o	0.035	0.038	0.03	0.021

t_o	38.78	38.21	39.66	41.82
Pr_o	0.73	0.76	0.68	0.62
Loads on front face joints of the structure				
	938	934	385	224

At Third Floor (9.75m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	31.54	32.54	35.37	39.63
Scaled Distance	67.95	70.11	76.2	85.39
P_{so}	0.32	0.33	0.29	0.24
t_d	29.3	28.96	29.99	31.94
q_o	0.035	0.038	0.03	0.021
t_o	38.78	38.21	39.66	41.82
Pr_o	0.73	0.76	0.68	0.62
Loads on front face joints of the structure				
	938	934	385	224

At Fourth Floor (13m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	32.69	33.66	36.4	40.55
Scaled Distance	70.42	72.51	78.42	84.38
P_{so}	0.35	0.32	0.29	0.24
t_d	38.13	38.49	30.27	31.94
q_o	0.043	0.036	0.029	0.021
t_o	37.55	38.49	39.92	41.82
Pr_o	0.825	0.735	0.65	0.62
Loads on front face joints of the structure				
	938	954	385	224

At Fifth Floor (16.5m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	34.11	35.04	37.68	41.23
Scaled Distance	73.48	75.49	81.27	88.82
P_{so}	0.28	0.26	0.24	0.22

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t_d	30.29	40.9	31.99	32.16
q_o	0.015	0.023	0.02	0.02
t_o	39.94	40.9	41.64	43.73
Pr_o	0.64	0.58	0.53	0.48
Loads on front face joints of the structure				
	832	754	689	330

At sixth Floor (19.5m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	35.78	36.65	39.19	43.08
Scaled Distance	77.08	78.96	84.43	92.81
P_{so}	0.24	0.25	0.23	0.21
t_d	32.42	31.89	29.04	33.47
q_o	0.02	0.022	0.018	0.036
t_o	41.07	41.33	42.16	43.6
Pr_o	0.55	0.5	0.5	0.74
Loads on front face joints of the structure				
	715	650	650	307

At seventh Floor (22.75m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	37.65	38.48	40.43	44.64
Scaled Distance	81.11	82.9	87.1	96.17
P_{so}	0.24	0.24	0.2	0.25
t_d	31.99	31.89	33.35	29.93
q_o	0.02	0.021	0.016	0.022
t_o	42.13	41.85	43.57	41.27
Pr_o	0.54	0.53	0.47	0.56
Loads on front face joints of the structure				
	702	690	611	230

At eighth Floor (26m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	39.69	40.39	42.97	46.68

Scaled Distance	85.5	87.23	92.18	92.92
P_{so}	0.23	0.22	0.1	0.2
t_d	32.13	33.3	33.74	34.02
q_o	0.019	0.016	0.015	0.017
t_o	42.5	43.54	43.8	44.02
Pr_o	0.51	0.22	0.45	0.52
Loads on front face joints of the structure				
	663	690	611	187

At nineth Floor (26m) Distance				
	At point (4)	At point (1)	At point (2)	At point (3)
Blast (Kg)	100	100	100	100
Actual Distance	40.23	41.52	43.26	46.9
Scaled Distance	86.5	87.93	93.56	94.22
P_{so}	0.23	0.23	0.21	0.2
t_d	32.98	34.22	34.58	29.99
q_o	0.018	0.015	0.21	0.017
t_o	42.5	43.54	43.8	44.02
Pr_o	0.51	0.22	0.45	0.52
Loads on front face joints of the structure				
	663	690	611	187

Loads on side face joints of the structure

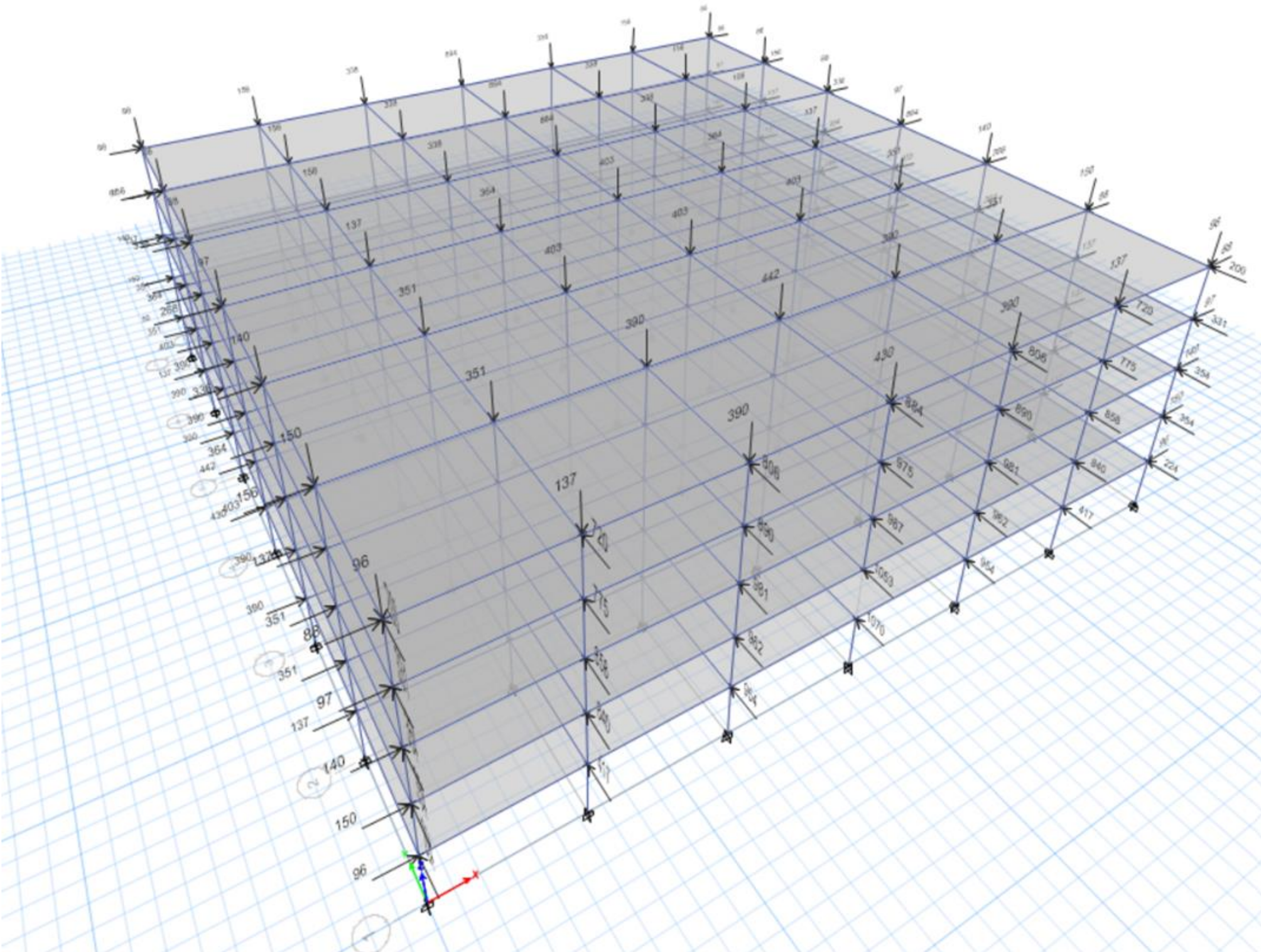
Story	At point (4)	At point (1)	At point (2)	At point (3)
Ground Floor	442	390	380	150
First Floor	430	390	351	150
Second Floor	403	364	351	140
Third Floor	400	338	337	140
Fourth Floor	330	338	312	140
Fifth Floor	330	310	310	140
Sixth Floor	351	300	300	136
seventh Floor	300	298	286	128
Eight Floor	300	273	260	120
Nineth Floor	300	273	260	120

Calculation of blast Forces for G+4 and G+9 story structure of standoff distance 60m and 100m.

G+4 & G+9 (60m) 100KG TNT				
At distance	Loads on front face joints of the structure			
	At point (4)	At point (1)	At point (2)	At point (3)
0m	331	330	335	166
3.25 m	330	329	328	165
6.5m	329	328	320	164
9.75m	329	328	320	157
13m	326	321	310	155
16.25m	316	311	304	165
19.5m	311	311	265	133
22.75m	311	265	258	125
26m	262	258	250	120
At distance	Loads on side face joints of the structure			
	At point (4)	At point (1)	At point (2)	At point (3)
0m	156	141	141	72
3.25 m	156	140	139	71
6.5m	151	136	135	69
9.75m	143	128	126	65
13m	141	128	126	64
16.25m	135	122	124	61
19.5m	129	118	115	58
22.75m	120	115	113	57
26m	115	103	105	50

G+4 &G+9 (100m) 100KG TNT				
At distance	Loads on front face joints of the structure			
	At point (4)	At point (1)	At point (2)	At point (3)
0m	172	171	170	90
3.25 m	172	171	163	89
6.5m	170	169	160	88
9.75m	169	165	158	86
13m	165	160	152	85
16.25m	163	311	304	165
19.5m	159	156	145	69
22.75m	158	152	145	66
26m	148	145	139	65
At distance	Loads on side face joints of the structure			

	At point (4)	At point (1)	At point (2)	At point (3)
0m	71	65	58	28
3.25 m	65	65	55	27
6.5m	63	63	54	27
9.75m	62	63	54	25
13m	61	61	51	25
16.25m	60	58	50	21
19.5m	58	56	48	20
22.75m	56	53	47	20
26m	49	48	47	20



3D view

CONCLUSION

When first floor column fails dur to blasting effect, the column on the floor above goes into tension leading to extra reinforcement.

Beams connected to the effected column will also demand for additional reinforcement due to removal of column.

Beam as well as column demanding more reinforcement but beams are not failed only columns failed.

- For G+4 story structure

When central column is considered to be affected with blasting then, adjacent column carries additional 14-30% Axial force.

When central column C22 is considered to be affected with blasting then, adjacent columns C15, C29, C23 carries additional 33%, 31%, 14% of axial force.

When corner column C43 is considered to be affected with blasting then, adjacent columns C36, C44, C37 carries additional 27%, 20%, 24% of axial force.

When corner column C1 is considered to be affected with blasting then, adjacent columns C8, C2, C9 carries additional axial force of 25%, 25%, 24% respectively.

- For G+9 story structure

When central column is considered to be affected with blasting then, adjacent column carries additional 15-30% Axial force.

When central column C10 is considered to be affected with blasting then, adjacent columns C9, C11, C39 carries additional 30%, 31%, 15% axial force.

When corner column C7 is considered to be affected with blasting then, adjacent columns C6, C8, C29 carries additional 17%, 23%, 24% axial force.

When corner column C13 is considered to be affected with blasting then, adjacent columns C12, C19, C49 carries additional 15%, 23%, 25% axial force.

When corner or central column fails subjected to blast load then adjacent columns are failed at terrace floor.

It is also noted that if the blast load is acting on the longer span, the structure is slightly more susceptible than the case if the blast load is acting on the shorter span.

When any column fails subjected to blast load, then adjacent columns will take additional load.

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