Behavior of RC Structure Subjected to Blast Load

Diksha D. Menghare[1], Prof. Raju A. Bondre[2]

[1]M . Tech. Student, Dept of civil engineering, RTMNU university ,INDIA

[2]Assistant Professor, Department of civil engineering, Gurunanak Institute of Technology, Nagpur,India 441501

***Abstract*—** As we know that nowadays the increase in the number of terrorist attacks especially in the last few years has shown the effect of blast load on buildings is a serious matter that should be taken into consideration in the design process. Although these kinds of attacks are exceptional cases, man-made disasters; blast loads are in fact dynamic loads that need to be carefully calculated just like earthquake and wind loads.

In that I have calculated the blast load manually by using IS code 4991-1968 and the analysis is carried out in multi-storeyed building by using STADD-Pro Software.

***Keywords*—** Blast load, dynamic load, earthquake & wind load, IS 4991-1968, STADD-Pro.

1. INTRODUCTION

Nowadays from the last past years the terrorist have targeted the multi-storeyed building to kill the number of people to show their and fear to the country and their weapon power. Due to increase in technology, the building in large cities are concentrated on the comfort of living and the safety against earthquake and wind loads but they are not concentrated on blast loads, so that the framework is totally collapsed during the terrorist blast.

The objective of this study is to shed light on blast resistant building design theories, the enhancement of building security against the effects of explosives in both architectural and structural design process and the design techniques that should be carried out. Firstly, explosives and explosion process have been presented to clarify the effects of explosives on buildings. To have a better understanding of explosives and characteristics of explosions will enable us to make blast resistant building design much more efficiently. Essential techniques for increasing the capacity of a building to provide protection against explosive effects discussed both with an architectural and structural approach.

Damage to the assets, loss of life and social panic factors that have to be minimized if the threat of terrorist action cannot be stopped. Designing the structures to be fully blast resistant is not an realistic and economical option. However current engineering and architectural knowledge can enhance the new existing buildings to mitigate the effects of an explosion.

Blast resistant design should provide a level of safety for persons in the building that is no less than that for persons outside the buildings in the event of an explosion. Evidence from past incidents has shown that many of the fatalities and serious injuries were due to collapse of buildings onto the persons inside the building. This objective is to reduce the probability that the building itself becomes a hazard in an explosion.

Preventing cascading events due to loss of control process units not involved in the event is another objective of blast resistant design. An incident on one units should not affect the continued safe operation or orderly shutdown of other units.

Preventing or minimizing financial losses is another objective of blast resistant design. Building containing business information, critical or essential equipment expensive and long lead time equipment, or equipment which if destroyed, would constitute significant interruption or financial loss to the owner should be protected.

Objective of the blast design

The primary objectives for providing blast resistant design building are:

- Personnel safety
- Controlled shutdown
- Financial consideration

Blast resistant design should provide level of safety for persons in the building that is no less than that for persons outside the building in the event of an explosion.

Preventing cascading events due to loss of control of process units not involved in the event is another objective of blast resistant design.

Preventing or minimizing financial losses is another objective of blast resistant design. Building containing business information, critical or essential equipment, expensive and long lead time equipment which if destroyed, would constitute significant interruption or financial loss to the owner should be protected.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 06 | June -2020 ISSN: 2582-3930

2. Types of explosion

Mainly there are two types of explosions

2.1 Unconfined Explosion

Unconfines explosion can occure as an air-burst explosion,

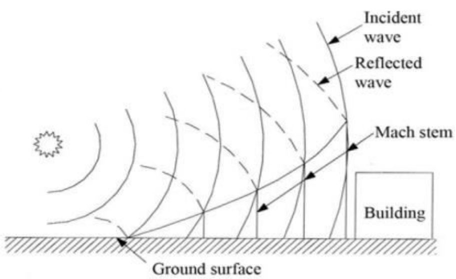

Figure 2.1: Air burst with ground reflections

the detonation of the high explosive occurs above the ground level and intermediate amplification of the wave caused by ground reflections occurs prior to the
arrival of the initial blast wave at a building Figure 2.1. As the shock wave continues to propagate outwards along the ground surface, a front commonly called a Mach stem is formed by the interaction of the initial wave and the reflected wave.
However a surface burst explosion occurs when the detonation occurs close to or on the ground surface. The initial shock wave is reflected and amplified by the ground surface to produce a reflected wave. Figure 2.2. Unlike the air burst, the reflected wave
merges with the incident wave at the point of detonation and forms a single wave. In the majority of cases, terrorist activity occurres in built-up areas of cities, where devices are placed on or very near the ground surface.

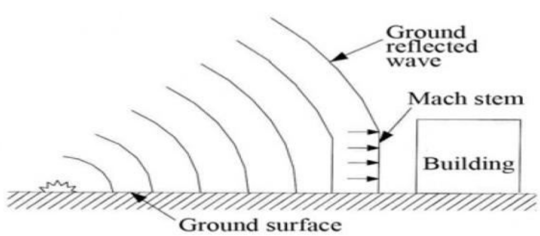

Figure 2.2: Surface burst

2.2 Confined Explosions

When an explosion occurs within a building, the pressures associated with the initial shock front will be high and therefore will be amplified by their reflections within the building.

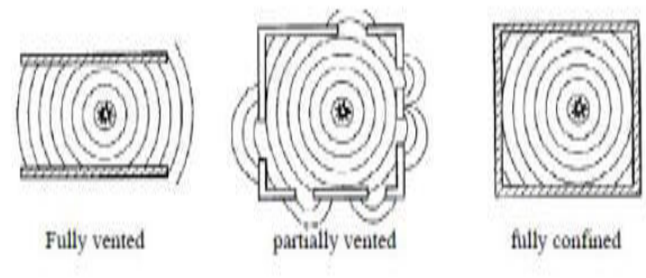

Figure 2.2: Fully vented, partially vented and fully confined explosions

This type of explosion is called a confined explosion. In addition and depending
on the degree of confinement, the effects of the high temperatures and accumulation
of gaseous products produced by the chemical reaction involved in the explosion will
cause additional pressures and increase the load duration within the structure.
Depending on the extent of venting, various types of confined explosions are possible.
Figure2.3

3. Structural Aspect of Blast Resistant Building

The front face of a building experiences peak overpressures due to reflection of an external blast wave. Once the initial blast wave has passed the reflected surface of the building, the peak overpressure decays to zero. As the sides and the top faces of the building are exposed to overpressures (which has no reflections and are lower than the reflected overpressures on the front face), a relieving effect of blast overpressure is experienced on the front face. The rear of the structure experiences no pressure until the blast wave has traveled the length of the structure and a compression wave has begun to move towards the centre of the rear face. Therefore the pressure built up is not instantaneous. On the other hand, there will be a time lag in the development of pressures and loads on the front and back faces. This time lag causes translational forces to act on the building in the direction of the blast wave.

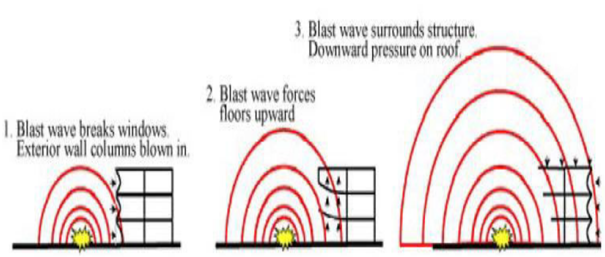

Figure:3.1 Sequence of air-blast effects

Blast loadings are extra ordinary load cases however, during structural design, thiseffect should be taken into account with other loads by an adequate ratio. Similar to the static loaded case design, blast resistant dynamic design also uses the limit state design techniques which are collapse limit design and functionality limit design. In collapse limit design the target is to provide enough ductility to the building so that the explosion energy is distributed to the structure without overall collapse. For collapse limit design the behavior of structural member connections is crucial. In the case of an explosion, significant translational movement and moment occur and the loads involved should be transferred from the beams to columns. The structure doesnt collapse after the explosion however it cannot function anymore.
Functionality limit design however, requires the building to continue functionality after a possible explosion occurred. Only non-structural members like windows or cladding may need maintenance after an explosion so that they should be designed
ductile enough. When the positive phase of the shock wave is shorter than the natural vibration period of the structure, the explosion effect vanishes before the structure responds. This kind of blast loading is defined as impulsive loading. If the positive phase is
longer than the natural vibration period of the structure, the load can be assumed constant when the structure has maximum deformation. This maximum deformation is a function of the blast loading and the structural rigidity. This kind of blast loading is defined as quasi-static loading. Finally, if the positive phase duration is similar to the natural vibration period of the structure, the behavior of the structure becomes quite complicated. This case can be defined as dynamic loading. Frame buildings designed Figure 4.2: Enhanced beam-to-column connection details for steelwork and reinforced concrete to resist gravity, wind loads and earthquake loads in the normal way have frequently

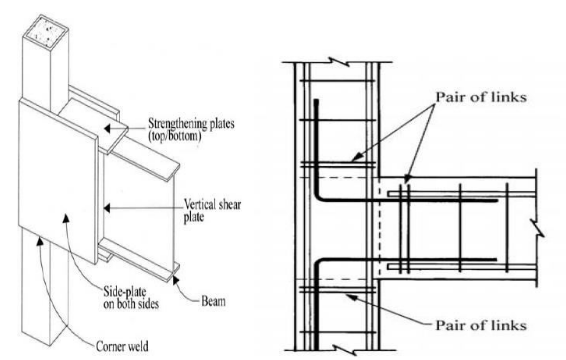

Figure 3.2: Enhanced beam-to-column connection details for steelwork and reinforced concrete

to resist gravity, wind loads and earthquake loads in the normal way have frequently been found to be deficient in two respects. When subjected to blast loading; the failure of beam-to-column connections and the inability of the structure to tolerate load reversal.Beam-to-column connections can be subjected to very high forces as the result of an explosion. These forces will have a horizontal component arising from the walls of the building and a vertical component from the differential loading on the upper and lower surfaces of floors. Providing additional robustness to these connections can be a
significant enhancement. In the connections, normal details for static loading have been found to be inadequate for blast loading. Especially for the steelwork beam-to-column connections, it is essential for the connection to bear inelastic deformations so that the moment frames could still operate after an instantaneous explosion. Figure 2.8 shows the side-plate connection detail in question . The main features to note in the reinforced concrete connection are the use of extra links and the location of the starter bars in the connection Figure 2.8. These enhancements are intended to reduce the risk of collapse or the connection be damaged, possibly as a result of a load reversal on the beam. It is vital that in critical areas, full moment-resisting connections are made in order to ensure the load carrying capacity of structural members after an explosion. Beams acting primarily in bending may also carry significant axial load caused by the blast loading. On the contrary, columns are predominantly loaded with axial forces under normal
loading conditions, however under blast loading they may be subjected to bending. Such forces can lead to loss of load-carrying capacity of a section. In the case of an explosion, columns of a reinforced concrete structure are the most important members that should be protected. Two types of wrapping can be applied to provide this. Wrapping with steel belts or wrapping with carbon fiber reinforced polymers (CFRP). Cast-in situ reinforced concrete floor slabs are the preferred option for blast resistant buildings, but it may be necessary to consider the use of precast floors in some circumstances. Precast floor units are not recommended for use at first floor where the risk from an internal explosion is greatest. Lightweight roofs and more particularly, glass roofs should be avoided and a reinforced concrete or precast concrete slab is to be preferred.

3.1 Structural Failure

An explosion will create blast wave. The air-blast shock wave is the primary damage mechanism in an explosion. The pressures it exerts on building surfaces may be several orders of magnitude greater than the loads for which the building is designed. The shock wave will penetrate and surround a structure and acts in directions that the building may not have been designed for, such as upward force on the floor system. In terms of sequence of response, the air-

blast first impinges on the weakest point in the vicinity of the device closest to the explosion, typically the exterior envelope of the building. The explosion pushes on the exterior walls at the lower stories and may cause wall failure and window breakage. As the shock wave continues to expand, it
enters the structure, pushing both upward and downward on the floor slabs

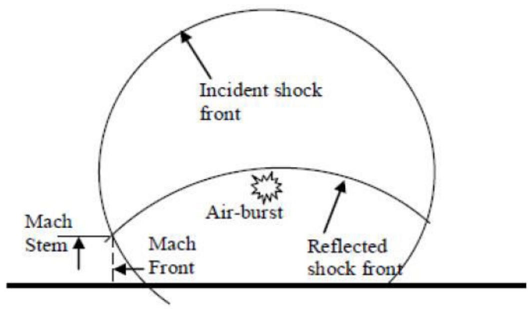

Figure 3.3: Shock Front from Air Burst

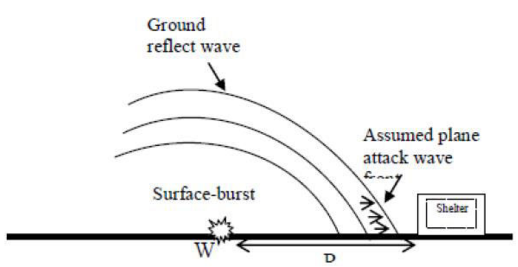

Figure 3.4: Shock Front from Surface Burst

3.2 Comparison of Blast And Seismic Loading

Blast wave and seismic loading are two different type of extreme force that may cause structural failure. However, they share some common similarities. Similarities between seismic and blast loading includes the following:

1. Dynamic loads and dynamic structural response.
2. Involve inelastic structural response.
3. Design considerations will focus on life safety as opposed to preventing structural damage.
4. Other considerations: Nonstructural damage and hazards.
5. Performance based design: life safety issues and progressive collapse.
6. Structural integrity: includes ductility, continuity, and redundancy; balanced design. The differences between these two types of loading include:

- Blast results in direct pressure loading to structure; pressure is in all directions, whereas a Seismic event is dominated by lateral load effects.
- Blast loading is of higher amplitude and very short duration compared with a seismic event.
- Magnitude of blast loading is difficult to predict and not based on geographical location.
- Blast effects are confined to structures in the immediate vicinity of event because pressure decays rapidly with distance; local versus regional even.
- Progressive collapse is the most serious consequence of blast loading.

3.3 Damage Evaluation Procedure For Building Subjected To Blast Impact

1. 1.Slab failure is typical in blasts due to large surface area subjected to upward pressure not considered in gravity design.
2. 2. Small database on blast effects on structures.
3. 3Seismic-resistant design is mature compared with blast-resistant design. In summary, while the effect of blast loading is localized compared with an earthquake,
4. The ability to sustain local damage without total collapse (structural integrity) is a key similarity between seismic-resistant and blast-resistant design. In this study, the evaluation data that had been listed in inspection form is adapted and modified from
5. Inspection form for building after an earthquake. Even though, seismic loading will cause global response to building compared to blast loading which will cause localized response, but similar damage assessment procedure could be used.

4. METHODOLOGY

In this present work a **G+6** Storey building having a dimension such as,

- Overall height of building is 21 m.
- Width of building is 15.5 m.
- Length of building is also 15.5 m.
- Size of Beam is 230 mm X 400 mm.
- Size of Column 400 mm X 400 mm.
- Slab thicknesss is 120 mm.
- Outerwall thickness is taken as 230 mm.
- then,
- Innerwall thickness is taken as 115 mm.
- Dead load (IS 875-Part I) **:**
  3 KN/m^2 for slab
  12 KN/$m^2$for outer wall
  6 KN/$m^2$for inner wall

- Live load is taken as $3 KN/m^2$ as per (IS 875- part II)

Load combination :
1.2 (dead load + live load)
1.5(dead load + live load)

Blast load calculation is done by manuaaly by using IS 4991-1968.

- **Properties of material considered such as**
Grade of concrete = M25
Grade of steel = Fe415
Density of concrete= $25 KN/m^3$
Density of steel = 78 KN/m^3
Poisson's ratio = 0.2

- **Building description**
In this this present work the blast load is applied on G+6 Storey building having height 21 m. each storey having height 3 m. The width & the lenght of the building is 15.5 m. The no. of bays in X & Y direction is 3.

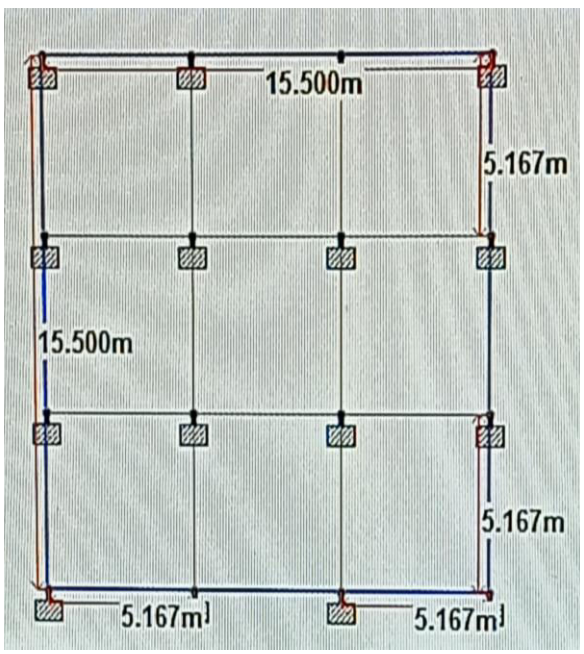

Fig- 4.1 Top view of proposed Plan

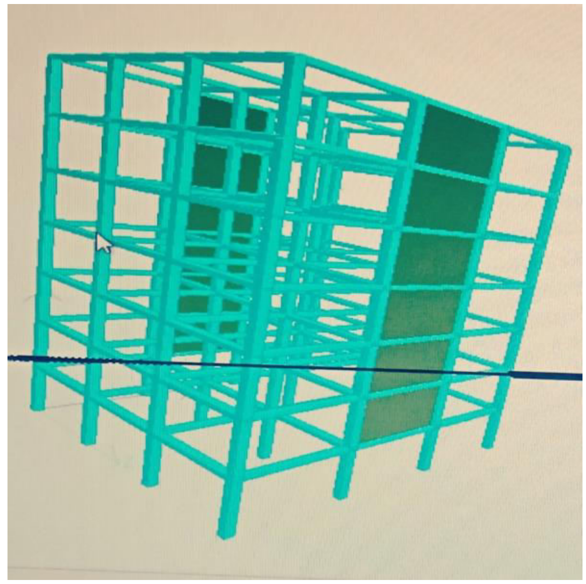

Fig 4.2: Isometric view of G+6 Storey building.

The building subjected to detonation amount of 0.1 tone, 0.2 tone, 0.3 tone considered from a distance of 30 m, which is obtained from the IS 4991-1968 from table no 7 based on the type of building. It was analyzed in STADD Pro by using Time History method.

5. CALCULATION OF BLAST LOAD PARAMETER MANUALLY

The detonation amount of 0.1 tone , 0.2 tone, and 0.3 tone is considered for study. The source of blast is considered from 30 m. The various parameter of blast load is obtained such as Pro, Pso from table no. 1 of IS 4991-1968.
We adopt the source at a point (0, 1.5, 0)

Table 1 – represents the distance and the target.

Coordinates of point of interest			**Distance between source and target**	**slab**
30	1.5	0	30	
30	1.5	6.667	30.76	SLAB 1
30	1.5	10.33	31.76	
30	4.5	0	30.33	
30	4.5	6.667	31.05	SLAB 2
30	4.5	10.33	32.04	
30	7.5	0	30.92	SLAB3
30	7.5	6.667	31.63	
30	7.5	10.33	32.60	SLAB 3
30	10.5	0	31.78	
30	10.5	6.667	32.47	SLAB4

30	10.5	10.33	33.42	
30	13.5	0	32.89	SLAB5
30	13.5	6.667	33.56	
30	13.5	10.33	34.48	
30	16.5	0	34.23	SLAB6
30	16.5	6.667	34.88	
30	16.5	10.33	35.76	
30	19.5	0	35.78	SLAB7
30	19.5	6.667	36.39	
30	19.5	10.33	37.24	

Table 2- blast load on front face of the building

slab	Scaled distance	Pro(kg/m$^{2)}$	Pro(KN/m$^{2)}$	A(m$^{2)}$	Force (KN)
SLAB 1	65	0.87	77	2.7	207
	65	0.80	77	2.7	207
	67	0.75	73	2.1	153
SLAB 2	65	0.79	77	2.7	207
	66	0.77	75	2.7	202
	67	0.75	73	2.1	153
SLAB 3	66	0.77	75	2.7	202
	67	0.75	73	2.7	197
	68	0.71	69	2.1	144
SLAB 4	68	0.71	69	2.7	186
	68	0.71	69	2.7	186
	70	0.69	67	2.1	140
SLAB 5	70	0.69	67	2.7	180
	71	0.69	67	2.7	180
	72	0.62	65	2.1	136
SLAB 6	72	0.67	65	2.7	175
	73	0.65	63	2.7	170
	74	0.64	62	2.1	130
SLAB 7	76	0.60	58	2.7	156
	76	0.60	58	2.7	156
	77	0.59	57	2.2	119

6. ANALYSIS OF BLAST LOAD ON STRUCTURE

Whenever the blast loading condition apply on the building the front face experiences maximum over pressure due to reflection. The sides and terrace of the building experiences no reflected waves. The back side of 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.

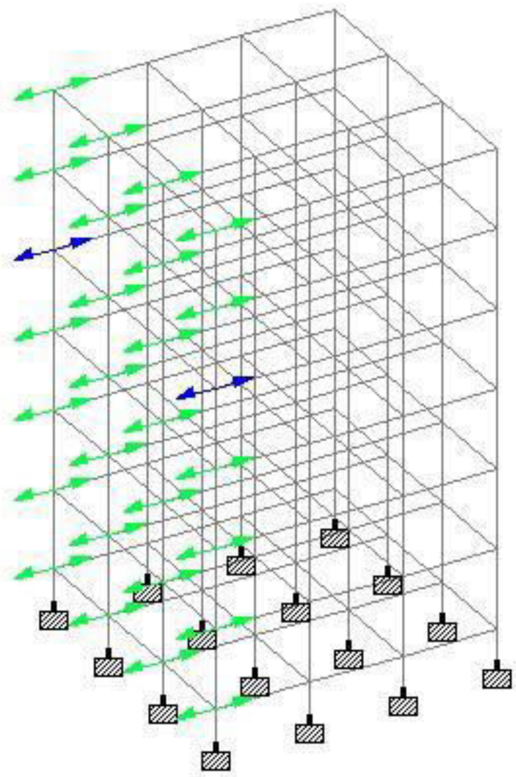

Fig-6.1 : Application of Blast load

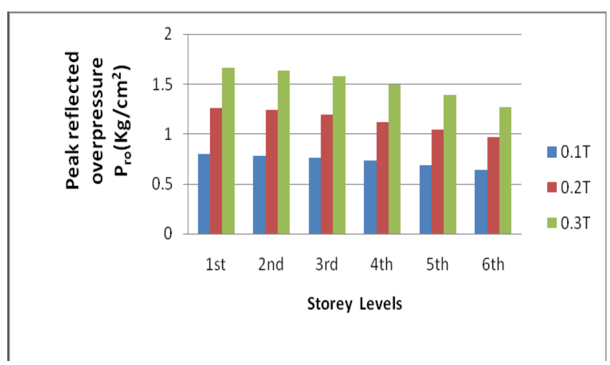

Chart-1: Blast pressure variation with Charge weight

7. CONCLUSION

The aim in blast resistant building design is to prevent the overall collapse of G+6 Storey building and fatal damages. Despite the fact that, the magnitude of the explosion and the loads caused by it cannot be anticipated. In the design process it is vital to determine the potential danger and the extent of
this danger. Most importantly human safety should be provided. Moreover, to achieve functional continuity after an explosion, architectural and structural factors should be taken into account in the design process, and an optimum building plan should be put together.

References

[1] M. Meghnath and T. Reshma (2017) worked on "Blast analysis and blast resistant design of RCC Residential building"

[2] Mayor Baxani et al. (2015) worked on "The dynamic response of Masonry wall subjected to blast load."

[3] M. R. Wakchaure and Seema Borole, (2013) worked on "Comparison of Maximum Stress distribution of Long & Short Column due to sLoading"

[4] Edward Eskew & Shinae Jang, (2012) has worked on "Impact and Analysis for Buildings under Terrorist Attacks"