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Analytical Assessment of Extreme Loads on Reinforced Concrete Frame

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ABSTRACT

Terrorist attack, now a days is becoming a common phenomenon for the world and it is a challenge for a structural engineer to design blast resistant structures. It is very difficult to design blast proof structure but blast resistant structure is possible to design. A bomb explosion near to structure or within the structure can cause catastrophic damage on entire building frames, walls, slabs, doors, glass panels and surrounding structures. This leads to severe loss of life and injuries for the people. Blast effect depends upon the standoff distance and explosive types. Large catastrophic damage from the gas explosion applies more load than designed loads. Blast load is also dynamic load which can be applied as a lateral load or in the pressure form on front face of the building. The analysis and design of blast resistant structure requires detailed understanding of blast loads and dynamic response of various structural elements. This paper deals with the blast response of reinforced concrete frame at different standoff distance and different charge weight for multi-story and single storey. Variation in deformation, velocity, acceleration of the structure is explained on the basis of analytical results.

Keywords

blast resistance; analysis; ansys; RC frame;extreme load.

1. INTRODUCTION

1.1 General

In the past few decades considerable stress is given to problems subjected to blast loads due to increased terrorist attacks on the structures by explosives. Multi-storey structure is highly vulnerable to damage by blast explosion. Terrorist attack on US embassies in Nairobi in1998, Murrah federal building in okhlama city in 1995 and world trade centre in new York 1993 have demonstrated the need of assessment of blast loads on affected structures to overcome from the future attacks. conventional structure are not capable to resist the blast effect as they are designed for normal gravity loads , structures can be design to resist blast effect but cannot be made blast proof.

To design blast resistant structure, is much uneconomical. Number of important parametric study should be done especially blast response, reinforcement detailing, nonlinear behaviour of the structures and the used material under high strain rate should be analysed which is different from normal gravity load construction. Use of glass materials should be avoided.

Generally, explosion states the rapid, sudden, release of large amounts of energy within a limited space. The explosion is a phenomenon of rapid and abrupt release of energy. An explosion in air generates a pressure bulb, which grows in size at supersonic velocity. The resulting blast wave releases energy over a small duration and in a small volume, thus generating a pressure wave of finite amplitude, travelling radially in all directions. Explosive is widely used for demolition purposes in construction or development works. Explosions can be categorized on the basis of their nature as physical, nuclear and chemical events. Physical explosion states the rapid release of energy from catastrophic failure of cylinder of a compressed gas, volcanic eruption or even mixing of two liquid at different temperature. Nuclear explosion states the release of energy from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the inner acting nuclei.

Chemical explosion states the release of energy by the rapid oxidation of the fuel elements (carbon and hydrogen atoms). The one-third portion of the chemical energy available in most high explosives is discharged during the ignition process. The residual two-third portion is discharged slowly as the detonation products combine with air and burn. This afterburning development has slight effect on the initial blast wave because it happens much slower than the original detonation process. On the other hand, the next stages of the blast wave can affect by the afterburning, especially for blasts in confined spaces. As the shock wave spreads out, pressures reduce quickly owing to geometric divergence and the consumption of energy in heating the air. Pressures also decrease rapidly over time and have a very short period of survival, calculated in milliseconds. Explosive materials can be classified according to their physical state as solids, liquids or gases. Solid explosives are mainly high explosives for which blast effects are best known.

The Explosion can occur as, Air burst, High altitude burst, under water burst, Underground burst, Surface burst. The discussion in this section is limited to surface burst.

Surface burst occur when the charged mass is placed at certain standoff distance and explosion takes place in the form of a hemispherical wave. The initial shock wave is reflected and amplified by the ground surface to produce a reflected wave. 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 occurred in built-up areas of cities, where devices are placed on or very near the ground

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 travelled 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.

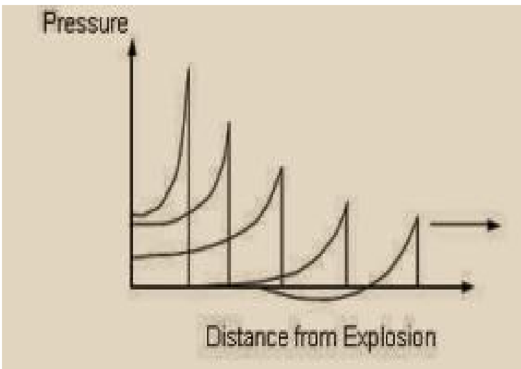

Figure 1. Response of explosive on structures with varying distance

1.2 Blast Wave Pressure – Time History

The pressure-time profile, two main phases can be observed portion above ambient is called positive phase of duration while that below ambient is called negative phase of duration. The negative phase is of a longer duration and a lower intensity than the positive duration. During the negative phase, the weakened structure may be subjected to impact by debris that may cause additional damage.

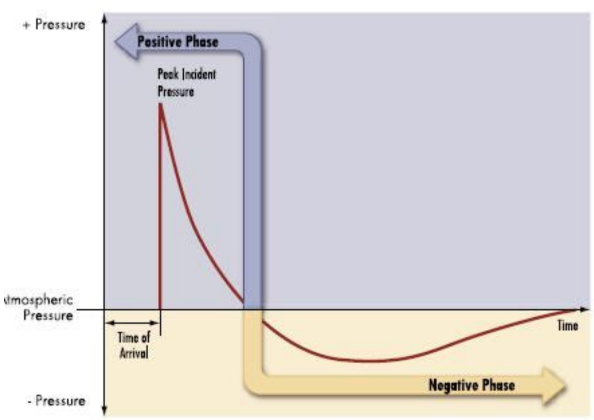

Figure 2. Pressure-Time curve

2. METHODOLOGY

The blast load depend on charge weight means explosive weight and standoff distance between the blast source and target. Consider the buildings subjected to a blast equivalent in yield to some kg of TNT at a certain standoff distance. For dynamic analysis of structures, the blast effects are most conveniently represented by a loading-time history that is applied to the structural members as transient loading. The magnitude and the pressure-time history of the blast load is calculated using the Table 1 given in IS 4991-1968. The method used to calculate the blast load is to divide the front face into a number of well-defined grids and to calculate the total impulse on each grid point. It should be assumed that time varying triangular forces are acting on each beam-column joint on the front face of the buildings. These pulses have zero rise time and decay linearly.

The blast is applied in X direction only on the middle panels as maximum pressure will act at that point in hemispherical form. The total 16 column beam joints are on the front face of building. The forces due to blast loading should be applied to the buildings as triangular loading functions calculated separately for each joint of the front face of the building, taking into account the distance to each joint from the source of explosion. Once the reflected pressure at each beam-column joint is calculated it should be multiplied with Tributary area to get the peak load at that joint. Rcc frame is analysed with ansys 12.0 civil fem with geometric non linearity, static analysis, transient analysis is also done in order to find the fluctuation of the frame within given time.

3. ANALYTICAL ASSESSMENT

As a case study four story frame reinforced concrete symmetrical structure with 4 m and 3 bays each side was used. The story height kept 3 m. Dimensions of the column assumed 450x450 mm and the beam was 350x350 mm each. Geometry is analysed in stadd pro before being used in ansys for reinforcement detailing and designed for worst case. Different model are used to check the deflection with variation in explosive weight and standoff distance to check the strength of the frame as a normal gravity loads. Displacement time graph are observed in analysis.

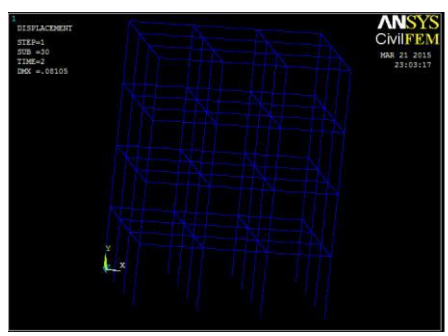

Figure 3. Four storey RC frame

4. ANALYTICAL RESULTS

These loads are given inputs to the software as time history function. Time history analysis is carried out by considering non-linearity and response up to 2 second can be drawn. After analyzing following plot results appeared on top storey. Plot function of 100kg TNT transient loading are given below

Table 1. For 100kg TNT

floor	point	Standoff distance (R)	Scaled distance (Z)	Pressure (kg/cm^2)	Area(A)	Time (Td)	Force(kn)
1	2	30.03	64.99	0.81	12	19.3	953
	3	30.03	64.99	0.81	12	19.3	953
2	2	30.40	65.83	0.78	12	19.4	928
	3	30.40	65.83	0.78	12	19.4	928
3	2	31.0	67.3	0.75	12	19.5	882
	3	31.0	67.3	0.75	12	19.5	882
4	2	32.0	69.3	0.72	12	19.7	854
	3	32.0	69.3	0.72	12	19.7	854
5	2	33.0	71.9	0.33	12	19.9	397
	3	33.0	71.9	0.33	12	19.9	397

floor	point	Standoff distance (R)	Scaled distance (Z)	Pressure (kg/cm2)	Area(A)	Time (Td)	Force(kn)
1	2	30.03	40.75	2.10	12	25.4	2470
	3	30.03	40.75	2.10	12	25.4	2470
2	2	30.40	41.26	2.04	12	25.6	2400
	3	30.40	41.26	2.04	12	25.6	2400
3	2	31.0	42.10	1.96	12	25.8	2304
	3	31.0	42.10	1.96	12	25.8	2304
4	2	32.0	43.43	1.82	12	26.2	2140
	3	32.0	43.43	1.82	12	26.2	2140
5	2	33.0	44.78	1.68	12	26.6	1975
	3	33.0	44.78	1.68	12	26.6	1975

Table 2. For 400kg TNT

1. plot function of displacement Vs time

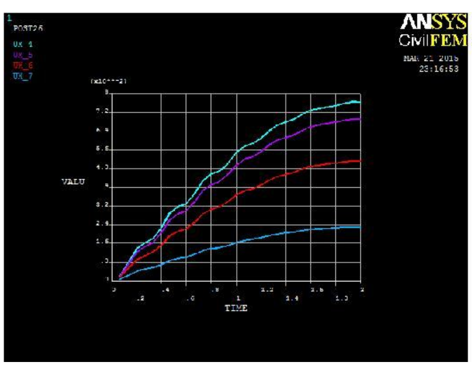

Figure 4. Variation in displacement of RC frame varying with height

2. Plot function of acceleration with time

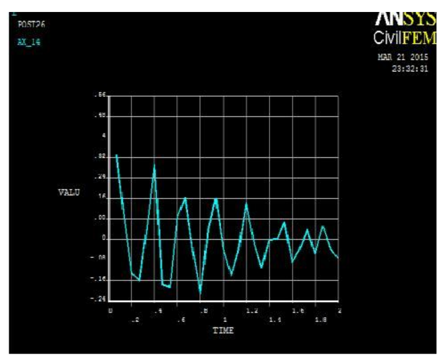

Figure 5 Acceleration-Time curve

3. Plot function of velocity with time

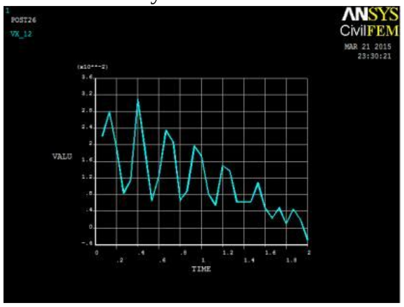

Figure 6. Velocity-Time curve

Nonlinear analysis of the geometry which satisfies the criterion value by its internal stress developed during load applied.

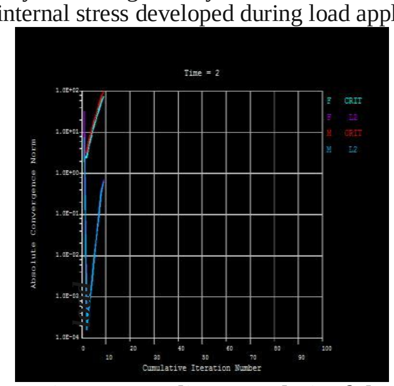

Figure 7. Nonlinear analysis of the geometry

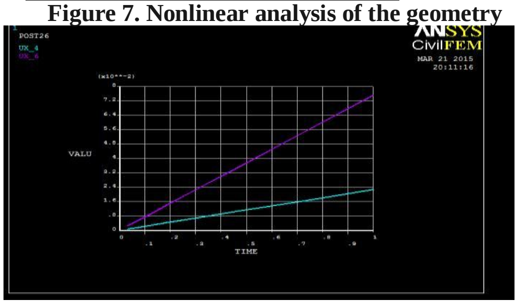

Figure 8. Displacement of top and middle panels of the RCC frame

5. COMPARISON OF DISPLACEMENT OF G+4 AT A STANDOFF DISTANCE AT 30M WITH RESPECTIVE CHARGE WEIGHT.

On increasing the charge weight at same standoff distance displacement is increasing along the height of the building.

On increasing the charge weight and if distance will be reduce closer to frame then deformation will come more or may be structure will get collapse ,top storey will be more effected.

Less effect will be on side and rear. Front face brick wall or other glass panels will get destroyed. If shell element will be there then it can resist more compared to normal bricks as better mechanical properties have shell elements.

Single storey structure will be less affected from explosive effects as per analysis even for high charge weight of explosive also. Following diagram will show analytical comparison of deflection of multi storey.

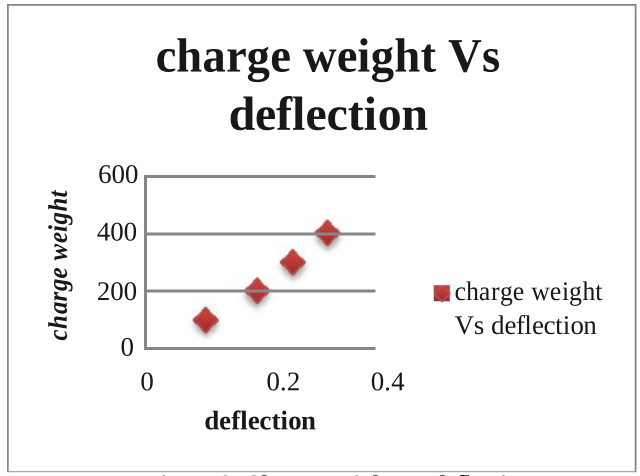

Figure 9. Charge weight Vs deflection

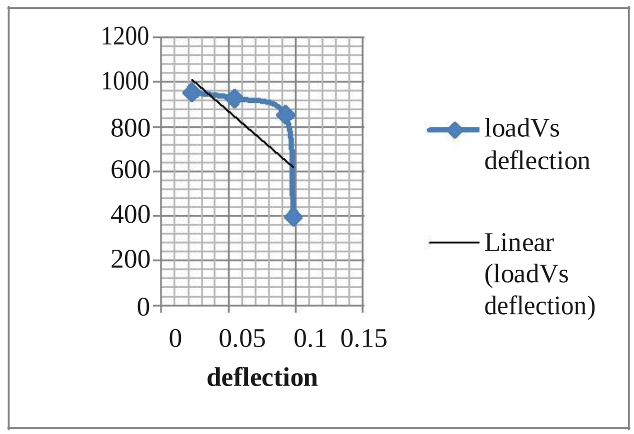

Figure 10. Load Vs deflection of 100kg TNT

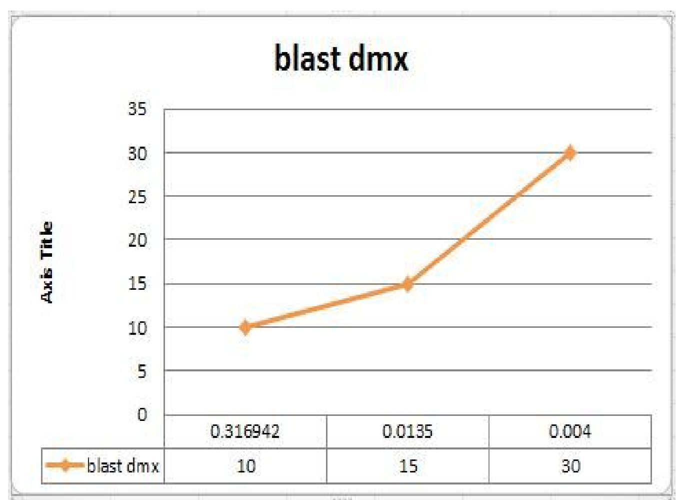

Fig Figure 11. Displacement graph of single storey with 100kg TNT for different standoff distances.

Table 3. Comparison of results

NUMBER OF STOREY	STAND OFF	CHARGE WEIGHT	Displacement (mm)	% DMX
4	30	100	80mm	
4	30	400	330mm	4.12
1	30	100	4	
1	15	100	13	3.25
1	10	100	316	
1	30	500	26	
4	15	100	130	
2	30	100	35	
2	30	1000	200	

6. CONCLUSIONS

In present study a R.C.C Frame was analyzed for blast load for 100 kg, 200kg, 300kg, 400kg.1000kgk of TNT placed at 30 m, 15 m, 10m distance from point of explosion. Blast load in each case is calculated from IS 4991-1968 and nonlinear direct integration time history analysis is carried out on Ansys12.0civil fem. After non-linear dynamic analysis of building subjected to blast load, following conclusions were drawn.

1) Variation of displacement is Non-Uniform along the height of building .top storey is fully affected compared to ground storey. Less storey structures will be less affected.

2) Performance level of building is reached to Collapse Point for minimum standoff distance.

3) Multi storey building frames that are designed for just normal loads perform reasonably well, without catastrophic collapse, when subjected to a blast that is equivalent to 100 kg TNT at a standoff distance of 30 m.

4) If blast is of 400 kg and 1000kg occur, performance level of building is critical.

5) For the important structures, blast analysis needs to carry out by keeping in view the terrorist activities in today's scenario.

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