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"Analysis and Corrective Study for RC Building under Explosion Loading"

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Abstract

Many of the existing buildings, which were not designed for blast loads, get damaged or even fully collapsed when subjected to such loadings. The main aim of this study is to evaluate the effects of explosion on the structure and to suggest various safety measures to protect those in/around the building, which may get killed or injured by the collapse of the structure. If the structure is designed to resist the blast load impact, the cost of the structure tends to be very high and talking about civil buildings cost of the structure is one of the most important constraints and therefore it is avoided.

In last few years, a number of public buildings, buildings of national and strategic importance have been targeted therefore there is a need to develop measures to reduce the hazard of such attacks. In case of accidental or intentional explosion building is subjected to blast impact and therefore dynamic analysis is required. Dynamic analysis computes the inertia forces developed on the structure when it is excited by means of dynamic loads applied suddenly (e.g., wind, explosion or earthquake). Dynamic analysis is done using ANSYS Workbench (Version 14.0) Explicit Dynamics.

In this study, dynamic analysis is performed in order to determine the effects of blast impact on the modeled structure, parameters considered in terms of energy in the analysis is compare with the manual calculation. Further, temporal behaviour of different parameters such as strain, stress,

deformation and pressure on the structure as well as parameters of explosive such as total energy, kinetic energy, internal energy and density of the explosive, results are studied. Analysis is carried out in two parts, in first part, the behaviour of a two by four bay three story rectangular shape frame when subjected to a large amount of explosive is studied. The distance between structure and explosive was varied from 10 m up to 25 m in longer as well as in shorter side of the structure. In the second part a G+7 story building is analysed

this building was subject to a explosion of half ton of TNT at a distance of 10m away from the structure.

The energy in the explosive is stored in form of potential energy and after detonation or deflagration energy released in form of kinetic energy. This released energy creates shock wave and push the surrounding away from the detonation, fragmentation throws shrapnel outward causes local damage to human beings as well as structure. It was observed that deformation in the structure is less when explosion takes place in front of shorter side, as well as pressure on the structure is less when explosion takes place in front of longer side. The stress developed in supporting column is much higher than the yield stress of concrete, therefore local failure of the main supporting column occurs. Due to this localized failure, the entire upper floor gets unsupported and collapse of structure occurs.

In order to prevent the collapse of structure, modifications such as heavy section, shear wall, and steel bracing were suggested. Feasibility of each of these methods is analyzed. From the analysis it was found that deformation increases in case of shear wall by 18% and stress reduce with 13.5% while in case of heavy section deformation reduces with 25% and stress reduces to 39%. Apart from these remedies, if any local failure occurs due to increased stresses, the collapse of the whole structure can be prevented with the use of alternate supporting members like steel bracing which leads to about 1.6% increase in the total cost of the structure. The use of heavier sections leads to an increment of about 0.8% in the costing and the same comes to be 0.9% when shear wall is considered.

It was observed that it is very difficult to design and costly to construct a structure for the forces acting at the time of blast. While another way to secure the structure from the blast is to mitigate the energy of explosive by proper arrangements of interior & exterior architecture as well as aesthetics & functionality of the building.

Introduction

In recent years due to different accidental or intentional, blasts all over the world, resulted in number of initiatives to study the resistance of structures to blast and to develop systems to reduce the hazard of such attacks. The main aim of these is to protect & provide safety to those who are in/around the building, and can be killed or injured by the collapse of the structure and the falling debris.

One of the main areas of research and development in this field is the progressive collapse prevention. From structural engineering and construction point of view structure must be designed so that it can withstand a terrorist bomb attack with minimum or no damage. Designing such a highly protected building requires a significant amount of funding as well as resources. In addition, to achieve the objective of the minimum damage, the designers may sacrifice the exterior and in some cases the internal aesthetics & functionality of the building. Although in case of military, the high cost of a building (like bunkers) can be justified but for civilian buildings, such high costs cannot be afforded and the loss of aesthetics & functionality may not always be acceptable. This was because of the assumption that civilian buildings had a very low probability to be a target of terrorist attack. But it is not so after events like April 19, 1995 Murrah Federal Office Building, Oklahoma City bombing, September 11, 2001 World Trade Centre, Pentagon, attacks. These recent events show the importance of study & design of blast resistant structures to withstand the main and secondary effects due to blast.

In recent times of heightened terrorist activities and alarming threats of future attacks, it has become of the utmost importance to develop blast resistant structures. In case of accidental or intentional blast problem is referred as a BLAST-IMPACT problem, this problem may be divided in two parts: the first part involves assessing the damage that a structure will suffer when it is hit by a blast wave of a specific strength, the second part deals with the design and testing of structures that are capable to withstand or mitigate the strength of the blast wave. One of the biggest challenges in this area is the lack of knowledge of the amount and the location of the explosive, especially in the case of a terrorist attack.

Past studies indicate that structures designed to resist earthquake show positive resistance for blast forces. As per IS 4991-1968 "Code of blast resistant design of structure for explosions above ground", Wind or earthquake forces shall not be assumed to occur simultaneously with blast effects. There is sometimes a misunderstanding about the blast resistance that is

provided by a building designed to resist earthquakes. Although there is some overlap between the disciplines (see Figure 1-1), mostly in the area of progressive collapse prevention, earthquake resistant buildings are unlikely to meet the direct effects of an air-blast loading acting on the exterior skin of a building. The reasons for the differences between these loading are as follows:

- Explosion loads act directly on the exterior envelope whereas earthquakes load act at the base of the building. Consequently the focus is on out of plane response for explosions and in plane response for seismic loads (see Figure 1-2)

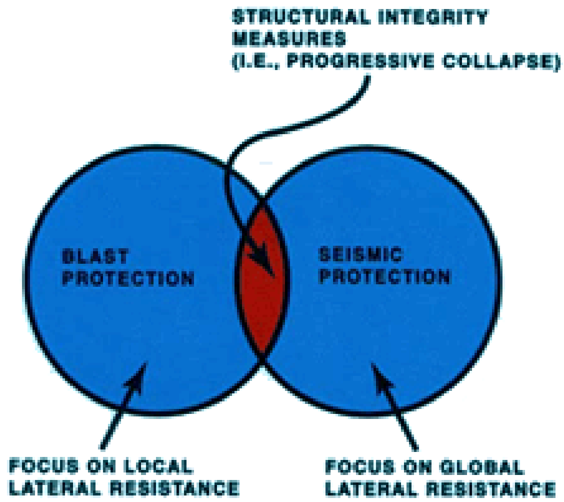

Figure 1- 1 Seismic v/s. blast overlap

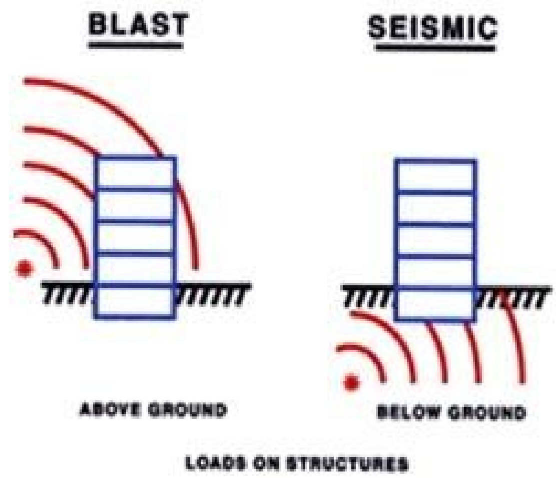

Figure 1-2 Seismic v/s. blast loading type.

- Explosion loads are characterized by a single high pressure impulsive pulse acting over milliseconds rather than the vibration loading of earthquakes which is acting over seconds (see Figure 1-3)
- Explosion loads generally cause localized damage whereas seismic loads cause global response (see Figure 1-4)

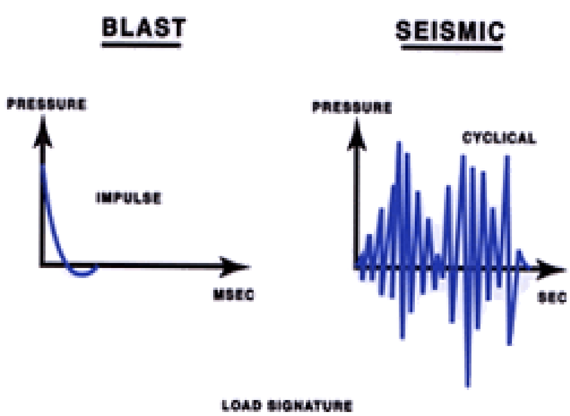

Figure 1-3 Seismic v/s. blast loading time histories

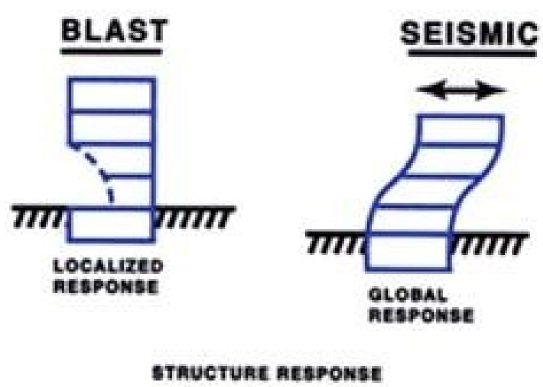

Figure 1-4 Seismic versus blast response

Methodology

In the current project blast analysis is performed on G+ 3 structures for blast of an explosive material at different distance from one of the face of the structure for same amount of explosive material.

For this analysis the methodology is as follows:

- An extensive survey of the literature on the blast analysis and there effects on the structure is performed.
- Based on the numerical and parametric study, a step by step procedure for the simplified blast analysis and there effects have been suggested.
- Dynamic analysis in ANSYS14.0 for evaluating energy of the explosive and its comparison with energy has been calculated manually.
- For determine the behaviour of explosive & effects of blast on structure, a problem of a G+ 3 structures having 2×4 bay is taken & analyzed for different stand-off distances with a large amount of explosive.
- After that a G+ 7 unsymmetrical structure is taken and analyzed for stand-off distances of 10 m with half ton of TNT explosive & determine the failure of vertical supporting member.
- Effects of explosive on the structure and there safety measures are determined.

Results & Discussion

In this study, dynamic analysis is performed in order to determine the effects of blast impact on the modeled structure, parameters considered in terms of energy in the analysis is compare with the manual calculation. Effects of the energy released from the explosive are study on a G+3 structure and then a G+7 actual structure is analysed and determine their vulnerability.

Various parameters considered in the analysis are listed below,

I. Total Energy, Internal Energy, Kinetic Energy & Density of Explosive
II. Total & Directional Deformation of Structure
III. Shear Elastic Strain of Structure
IV. Shear Stress of Structure
V. Pressure on the structure

Parameters considered during analysis for explosive in the time history are shows in figure 6- 1 to 6-4. As explosion takes place a large amount of energy released which depends on the amount/weight/type of explosive material. In the above analysis large amounts (1.6 ton) of explosive material TNT is used and detonate at different distance (10m, 15m, 20m and 25m). Figure 6-1 shows the change in total energy with respect to time and graph shows non linear decremental behaviour. Figure 6-2 and 6-3 shows the internal

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energy and density of the explosive with respect to time and graph shows exponential decremental behaviour due to exothermic reaction.

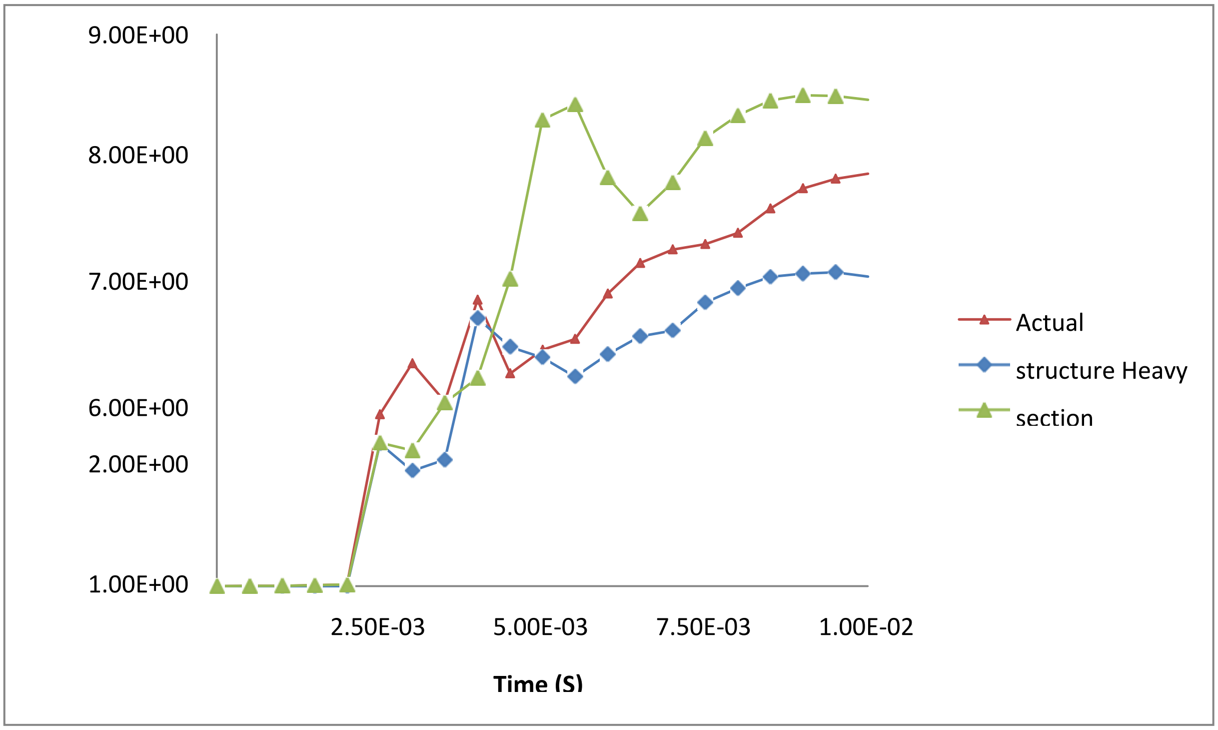

Figure 6-23 temporal variation of absolute deformation in the structure Table6-4 Absolute deformation in structure

Time	Total deformation		
	Actual structure	With heavy section	With shear wall
1.00E-03	0.00	0.00	0.00
1.50E-03	0.01	0.00	0.01
2.00E-03	0.02	0.00	0.02
2.50E-03	2.80	2.32	2.34
3.00E-03	3.63	1.88	2.21
3.50E-03	3.01	2.06	2.99
4.00E-03	4.67	4.37	3.39
4.50E-03	3.47	3.90	5.01
5.00E-03	3.85	3.73	7.61
5.50E-03	4.03	3.42	7.86

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6.00E-03	4.77	3.78	6.67
6.50E-03	5.27	4.07	6.08
7.00E-03	5.49	4.17	6.59
7.50E-03	5.58	4.62	7.31
8.00E-03	5.76	4.86	7.68
8.50E-03	6.16	5.04	7.92
9.00E-03	6.49	5.10	8.01
9.50E-03	6.64	5.12	7.99
1.00E-02	6.73	5.05	7.93

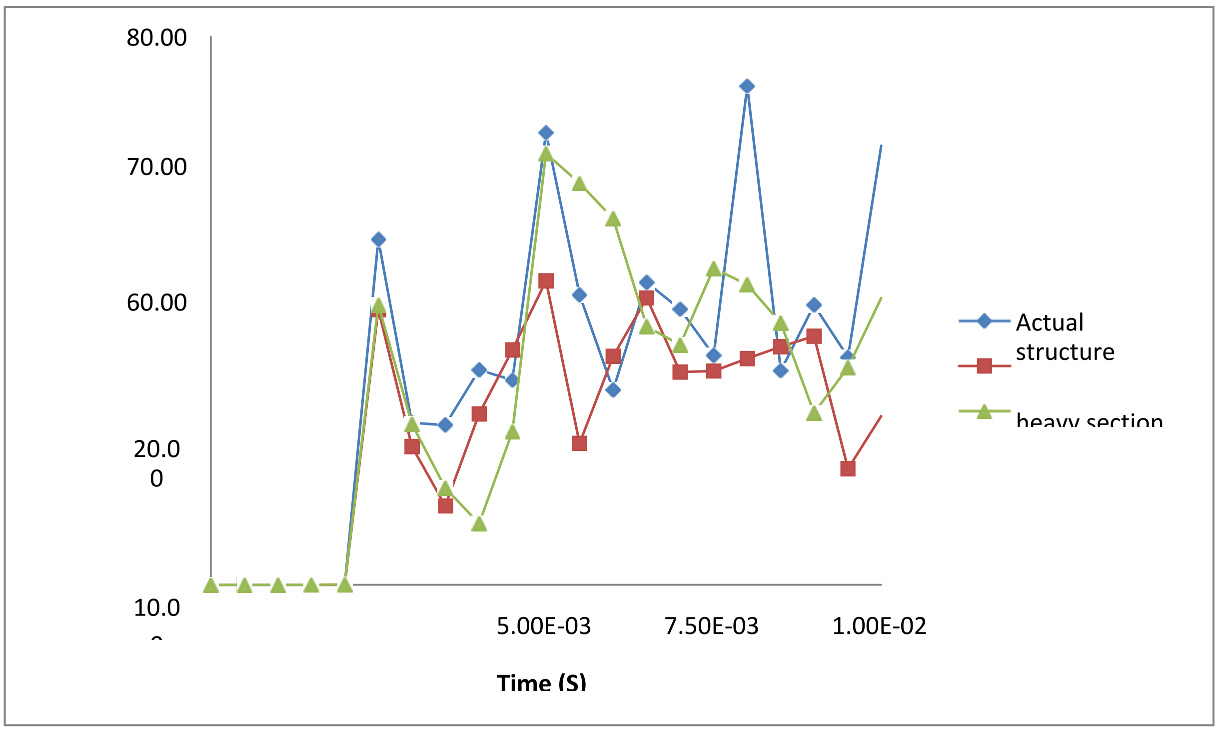

Figure 6-24 temporal variation of absolute shear stress in the structure Table 6-4 Absolute Shear stress in the structure

Time	Shear stress		
	Actual structure	With heavy section	With shear wall
1.00E-03	0.01	0.00	0.01
1.50E-03	0.02	0.00	0.04
2.00E-03	0.04	0.00	0.07

2.50E-03	50.39	40.16	40.86
3.00E-03	23.65	20.19	23.49
3.50E-03	23.31	11.53	14.14
4.00E-03	31.34	24.94	8.96
4.50E-03	29.88	34.29	22.39
5.00E-03	65.99	44.37	62.95
5.50E-03	42.30	20.64	58.59
6.00E-03	28.44	33.36	53.44
6.50E-03	44.14	41.87	37.69
7.00E-03	40.23	31.06	35.01
7.50E-03	33.48	31.22	46.18
8.00E-03	72.77	33.03	43.82
8.50E-03	31.25	34.75	38.23
9.00E-03	40.82	36.30	25.10
9.50E-03	33.21	16.97	31.71
1.00E-02	64.09	24.62	41.83

Conclusion

The blast phenomenon and the response of the structure for the explosion are studied. But practical analysis is very tedious, thus for the purpose simulation and real time analysis of the condition is required. By this analysis we concluded that energy released from the explosion decays with time and distance. Thus in order to keep the structure safe, we should consider all forces in action while designing the structure. Apart from this, proper arrangement of interior & exterior architecture as well as aesthetics & functionality of the building should be maintained.

1. Predict the position where probability of the explosion is high as well as affect the structure maximum.
2. Determination of the member failure due to air blast. Analysis result helps in adopting proper preventative measure. From the above analysis we conclude that heavy section is better from both structural and economical point of view.
3. Physical security & arrangements made should also help in decaying the energy of the explosive, following purpose may serve by:

- *Preventing and delaying the attack.* By making it more difficult to implement some (such as a parked car in the street). Delaying the attack by landscape/architectural feature and by making it more difficult to reach the intended target

- *Mitigating the effects of the attack*. If these precautions are implemented and the attack still takes place, then structural protection efforts will serve to control the extent and consequences of damage.
- *Layout of insecure area*. The insecure areas of the structure should be kept unmerged. For instance a separate lobby pavilion or loading dock area outside of the main building should be made and if it is not possible to place vulnerable areas outside the main building a "hard lines" or buffer zones should be created in building layout.

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