Structural Analysis of Blast Resistant Structures

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Abstract— The effect of blast load on buildings is, a serious matter that should be taken into consideration in the design Even though designing the structures to be fully blast resistant is not a realistic and economical option, we can improve the new and existing buildings to ease the effects of a blast. In this study, I've analyzed the effects caused by blast loads and to find how to reduce the effects using ETAB 2015, and from my studies, I conclude that the shear wall is resisting the blast loads than any other alternatives.

Key words: Blast Resistant Structures, Blast loading

I. INTRODUCTION

Blast loading has a serious effect on the buildings and hence it should be considered while designing. Although these attacks are, exceptional cases, man-made disasters (terrorist attacks); blast loads, are dynamic loads that should be precisely calculated just like earthquake and wind loads.

The main aim of this work is to give a requirement of protection against the explosions. The guidance describes the method for modifying the effects of detonations, thus providing protection for human being, structure and the important equipment inside.

In this work, I have explored the accessible literature on blast loads, the possibility of vulnerability evaluation, risk easing, details that develop ductility and structural response characteristics of structures with structural analysis software.

II. GENERAL, CHARACTERISTICS OF BLAST AND EFFECTS ON STRUCTURE

The quick discharge of energy due to a blast is characterized by air pressure and an audible blast. The energy released is divided into two different phenomena, thermal radiation and pairing with air and ground, known as air blast and ground shock. Air blast is the principle cause of the spoil to a building exposed to blast loading.

The conventional chemical charge is considered as sphere-shaped. The ground surface shock front at the contact burst is lateral. The effective yield is almost double of an equal detonation high in the air. This situation gives major effects.

As a consequence of the detonation, a shock wave is created in the air which moves outward in every directions. The initial positive pressure shock wave phase followed by a negative (suction) phase at any point as shown in Fig 1.

At any shock wave surface, the pressure increases instantly to top values of side-on overpressure and the dynamic pressure. The top value is affected by the size of detonation, the distance of the surface from the source.

Members subjected to blast pressures resist the applied force by internal stresses developed in them as in the case of normal loads. Nevertheless, dynamic properties of the member itself depend upon the effective load due to blast. Smaller is the effective load for design Longer the natural time period of the member.

Considering. The probability loading to be small, structures might be permitted to deform in the, plastic frange for economical design. Permitting plastic deformation increases the energy absorption, and has the further benefit that the effective. Time period of the structural element is elongated, thereby reducing the effective load for its design.

Most severe blast loading on the facedoffa structure is produced whenfthefstructure is oriented with the face normal to the path of propagation of the shock front. Nevertheless, for lack of known direction of future explosion, every face ofmthedstructure shall be considered as a front face.

The most significant parameters for blast loading, computations are the distance of the explosion point, from the structure of interest. By increasing the distance between the blast source and the target surface, decreases the peak pressure value and velocity of the blast wave, as shown in Fig 2. Only the positive phases of the blast waves are shown in Fig.2. The effect of distance on the blast features can be taken into account by the rough guide of scaling laws. These laws have the capability to scale constraints, which were defined through experiments, in order to be used for changing values of distance and charge energy release. The experimental results are in this way, generalized to include cases that are different from the initial experimental setup.

A pressure pattern is created which is different than the idealized time history due to the interaction between an object and a blast wave presented in Fig 1. The loads that, has to be withstood by a structures depends on various parameters, such as the type and weight off the explosive charge, the distance, of the explosion point, the structure's geometry and type, the communication of the waved with the environments and the ground, etc.

When the blast waved comes to contact with a rigid surfaced the pressured that is reflected is greater than the incident peak pressure so shown at Fig 1. The wave travels along airs particles, collided with the surface upon arrival.

Three types of reflection can take places depending on the angle of the reflecting surfaced with the propagation direction of the last wave. When the propagation direction of the wave intersects at a small oblique angle with the surface it causes the formation of an oblique reflection, whereas the third case is related today phenomenon known as Mach stem creation, which occurs each time the wave impinges on surface at a specific angle.

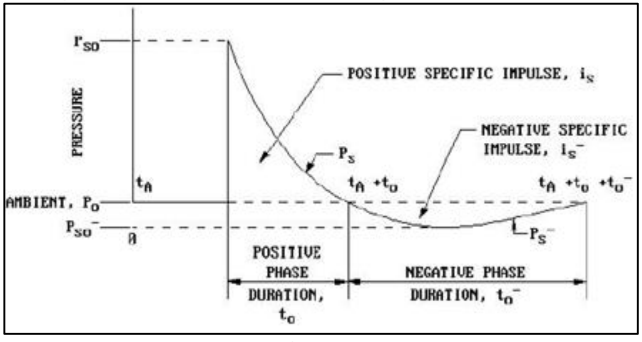

Fig. 1: Incident and reflected pressures on building

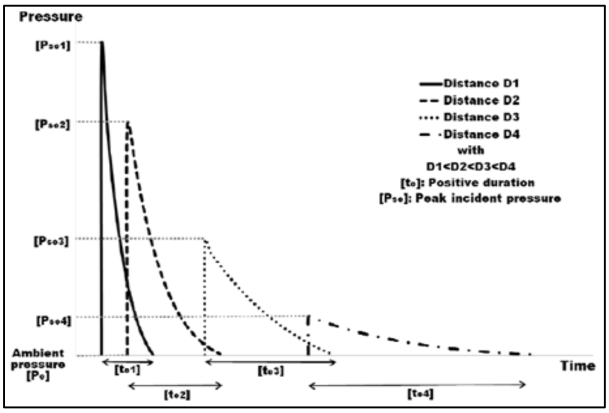

Fig. 2: Influence of distance on the blast positive pressure phase.

III. METHODOLOGY

In this analysis of a 2 storey structure in ETAABS, four different models are generated. The dimensional properties of frames chosen as follows:

The length of frame is 3 bays of 3.5m each and the width of frame is 4 bays of 3.5 m each

- Model 1: Normal framed structure of column size 400mm X 400mm, beam size of 300mm X 400mm
- Model 2: Increased cross section of column size 600mm X 600mm, and beam size of400 mm X 600mm
- Model 3: Addition of shear walls of thickness 150 mm around the structure on model 1
- Model 4: Addition of X shaped Steel bracing on model 1

And the different load cases that are used in these models are

1) Case 1: Blast of 100 kg explosive with standoff distance of 30m
2) Case 2: Blast of 100 kg explosive with standoff distance of 20m
3) Case 3: Blast of 300 kg explosive with standoff distance of 30m
4) Case 4: Blast of 300 kg explosive with standoff distance of 20m

IV. LOAD CALCULATIONS

Blast Load acting on structure due to explosion calculated using IS: 4991 - 1968 (Reaffirmed 2003) are shown below.

$$\text{Scaled Distance} = \frac{30}{(.1)^{1/3}} = 64.65$$

From IS 4991 1968, assuming Pu= I.00 kg/cm^2 and linearly interpolating between 63m and 66m for the scaled distance 64.65m the pressure are directly obtained:

$$P_{so} = 0.35 \text{ kg/cm}^2$$
$$P_{ro} = 0.81 \text{ kg/cm}^2$$
$$q_o = 0.042 \text{ kg/cm}^2$$

The scaled times to and td obtained from Table 1 for scaled distance 64.65m are multiplied by to .1$^{(1/3)}$ to get the values of the respective quantities for the actual explosion of .1 ton charge.

$t_o = 37.71 * (.1)^{1/3} = 17.5$ milliseconds

$t_d = 28.32 * (.1)^{1/3} = 13.15$ milliseconds

M =1.14

a = 344 m/s U = 392m/s = 0.392 m/millisecond

A. *Pressures on the Building*

Here H = 6 m, B = 10.5 m, and L = 10.5 m

Then S = 6 m

$$t_c = \frac{3S}{U} = \frac{3*6}{0.392} = 45.91 \text{ milliseconds} > t_d$$
$$t_c = \frac{L}{U} = \frac{10.5}{0.392} = 26.7856 \text{ milliseconds} > t_d$$
$$t_r = \frac{4S}{U} = \frac{4*6}{0.392} = 61.22 \text{ milliseconds} > t_d$$

As $t_r > t_d$ no pressure on the back face are considered. For roof and sides C_d = -0.4.

$$p_{so} + C_d * q_o = 0.35 - 0.4 \text{ x O } -042 = 0.33 \text{ kg/cm2}$$

1) *Loads on Front face joints*

Loads on Centre joints = 81 KN/ m^2 * 3.5*3 = 850.5 KN

Loads on Side joints = 81 KN/ m^2 * 3.5*$\frac{3}{2}$ = 425.25 KN

Loads on Edge joints = 81 KN/ m^2 * $\frac{3.5}{2}$*$\frac{3}{2}$ = 212.625 KN

2) *Loads on Roof and Side walls*

Loads on Centre joints = 33 KN/ m^2 * 3.5*3 = 346.5 KN

Loads on Side joints = 33 KN/ m^2 * 3.5*$\frac{3}{2}$ = 173.25 KN

Loads on Edge joints = 33 KN/ m^2 * $\frac{3.5}{2}$*$\frac{3}{2}$ = 86.625 KN

Bracing used: Channel section of ISLC 200.

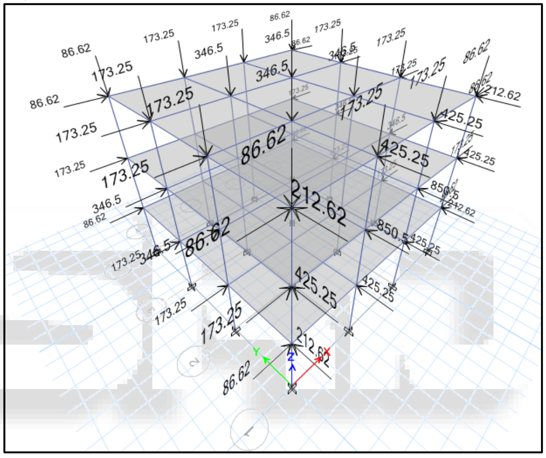

Fig. 3: Load application in case 1

V. RESULTS AND DISCUSSIONS

The analysis is done by ETAB 2015, Models are generated and loads are applied based on case (blast weight and standoff distance). Here live load on all floors taken as 3 KN/m^2 and the structure analyzed by non-linear static analysis since the loads are converted to static joint loads.

The maximum inter storey drifts are 54.3, 21.4 for 300 Kg blast load from 30 m and 20 m standoff distance, and 10.5,24 are the max storey drift for 100kg blast load from 30 m and 20 m standoff distance for the model 1. According to IS 1893 maximum allowable storey drift is 12 (.004* Storey height). So maximum storey drift are not satisfying IS code recommendation in model 1.

For all the cases in model 2 when we increase beam and column cross-section of structure compared to model one the maximum storey displacement are reduced by around 70 %., and maximum storey drift reduced by around 65%. The deformed shapes of the 4 models in case 1 is shown below.

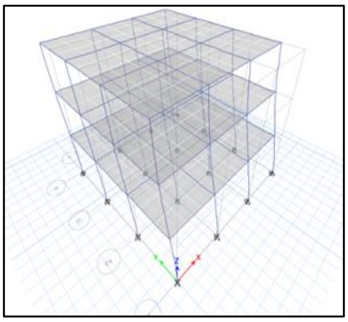

Fig. 4: Deformed shape of model 1

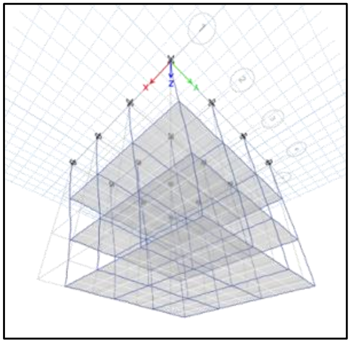

Fig. 5: Deformed shape of model 2

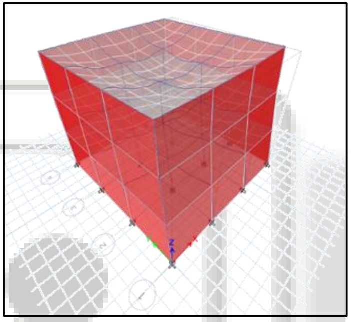

Fig. 5: Deformed shape of model 3

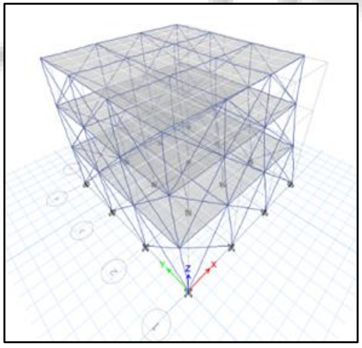

Fig. 6: Deformed shape of model 4

In model 3, addition of shear wall around the structure in model 1 results in reduction of maximum storey displacement by around 95 %, and max storey drift by around 95% compared to the maximum storey displacement and drift from model 1.In this model shear wall helps to decrease storey displacement effectively so that the maximum displacement and maximum story drift in this model are within the allowable max storey displacement and max story drift given by IS 1893.

In model 4, addition of steel bracing around the structure helps to reduce the maximum storey displacement by around 80% and maximum storey shear by around 80% compared to maximum storey displacement and maximum storey shear from model 1.

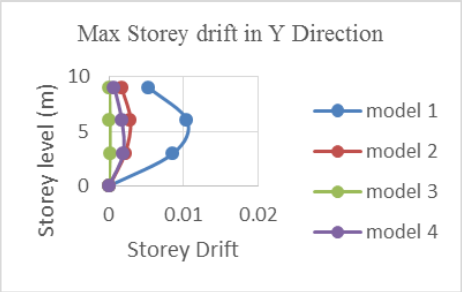

Fig.7: Maximum storey drifts in Case 1 in Y Direction

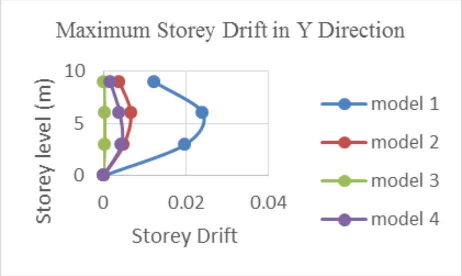

Fig. 8: Maximum storey drifts in Case 2 in Y Direction

Fig. 9: Maximum storey drifts in Case 3 in Y Direction

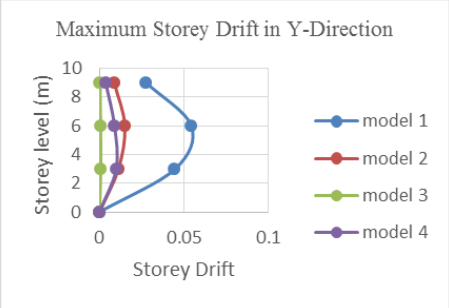

Fig. 10: Maximum storey drifts in Case 4 in Y Direction

Storey displacement in x direction and storey drift in x direction compared to storey displacement in y direction and storey drift in y direction are too low and are within the permissible limit

VI. CONCLUSION AND RECOMMENDATION

As per the result obtained from the analysis the following observations can be drawn:

1) As the blast load increases and standoff distance decreases the displacement and story drifts are increasing drastically in the structure. The blast parameters are depends on blast load and standoff distance. So the structure response depends on blast load and standoff distance values.
2) By increasing column and beam size in a structure will improve the resistance but it’s not practical in most cases due to serviceability problems because huge cross-section of beam and column needed to resist blast loads.

3) Addition of shear wall and steel bracing (x type) helps to resistant blast loads effectively. The steel bracing addition give good result but shear wall gives more desirable results than steel bracing, and it is economical too, compared to other methods to resist blast loads. A thorough comparative study could be done on structures for heavier blast loads and also by adding floors to find out the effects of blast loads in high rise structure.

The variation could be analysed on unsymmetrical structures compared to symmetric structures.

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