International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V70I11P205
Volume 70 Issue 11, 47-57, November 2022

Original Article

Effect of Building Aspect Ratio on Blast Response: A Hypothetical Case Study

I Krishna Chaitanya[1], Balaji K.V.G.D [2], M. Pavan Kumar[3], B. Sudeepthi[4]

[1,2,4]*Civil Engineering, Gitam (Deemed to be University), Andhra Pradesh, India.*
[3]*Civil Engineering, M.V.G.R College of Engineering, Andhra Pradesh, India.*

[1]*Corresponding Author: 11260214403@gitam.in*

Received: 17 July 2022 Revised: 31 October 2022 Accepted: 07 November 2022 Published: 26 November 2022

Abstract *- Public buildings became most targeted by terrorist attacks using explosives. Due to terrorist attacks on public buildings, there is a tremendous loss of life, the economy, and extensive damage to the structures. This is primarily due to the intensity of the explosive and the type of explosive used. When a blast occurs, buildings around the point of explosion or nearer to it will be affected and damaged. The intensity and scale of damage to the facilities will depend on a few parameters like type of structure, height, shape, durability, and age of the building. Hence, these parameters will be vital in analysing structures subjected to blast loads. In this view, nonlinear dynamic analysis was performed on regular framed buildings with different aspect ratios to study the blast response. A blast load of intensity 2500 Kg TNT charge weight at a standoff distance of 10 meters was applied on all the buildings as mentioned above as a time history function using the software package SAP 2000 v20. Parameters like lateral displacement and acceleration of all the buildings are observed to know the blast response of the considered building with different aspect ratios. Based on the analysis, the less affected geometric size of the building is found for implementing the safe design of the structure to mitigate the loss.*

Keywords *- Blast load, Time history analysis, Geometry of building, Inter Storey Drift, Energy absorption.*

1. Introduction

Some structures during their service life may experience explosive loads due to terrorist activities. Considering these unexpected terrorist acts, uncertainties in predicting blast load, and structural parameters damages, precise evaluation of the performances of structures under explosion loads is a demanding task. Nevertheless, explosions and their impacts could destroy structures, causing enormous casualties and property loss. In the recent past, various kinds of blasts occurred worldwide, leading to studies about the resistance of structures to blasts and numerous ways to mitigate the hazards. The behaviour of Building elements subjected to impact loads has been the focus of considerable research effort in recent years. Structures subjected to impact loading have gained importance, hence being considered for design, and the challenge of structural resistance under blast loads has been under research for several years and has been well advanced in the military community only. Therefore, most of these innovations are not available to the public and are only for military purposes. Nonetheless, some documentation that allows design engineers to predict the effects of an explosive blast is available. The buildings susceptible to damage due to blast and blast attacks in the country have lately activated the developers, architects, and engineers to quest for a solution to mitigate and lessen the effects of blasts on structures.

Geometry (size & shape) and structural configurations of the building play a vital role in blast response. Building plan aspect ratio is one of the key parameters that adversely influence the structure's response against various explosive loads. Most public and conventional buildings are planned with different plan aspect ratios based on the availability of plot area. So, there is a need to study the influence of blasts on the behaviour of buildings with different geometrical sizes and plan aspect ratios.

2. Literature Review

Zeynep Koccaz et al., Performed a study on the structural and architectural blast-resistant design of buildings and enhancement of structural safety and protection against the results of explosives and their effects on structures and concluded that, with the appropriate choice of structural systems, carefully designed columns and beam joints, properly designed structural components, moment frames which transfer sufficient force, and exceptional material [1]. T. P Nguyen and M.T Tran, by using MATLAB software, Vertical wall systems have been structured by plates restrained in corners and fixed on 4 sides for both linear and nonlinear blast loading, taking into consideration nonlinear dynamic analysis with cracked plate actions to determine the dynamic behaviour of various structural components [2]. Sun, Wen

Bin, et al. conducted a study on the assessment and design of structures exposed to blast-impacted loads and concluded that the building design subjected to blast-impact loads requires a brief understanding of the nature of blast wave phenomena as well as the response of dynamic effects to all structural elements [3]. Hrvoje Draganic and Vladimir Sigmund, due to a lack of regulatory requirements from national and European regulations on the validation of explosion-prone structures, the research presented a numerical example of a blast-exposed structure. It explained the method for calculating blast loads on buildings to familiarise the reader with the issue of blast load [4]. Jayashree et al. studied the dynamic response of a space-framed structure to blast loads. The displacement time history action to blast a load of frames with SIFCON and RCC is compared [5]. Quazi Kashif and M. B. Varma have investigated the effect of blast loading on a four-story RCC structure for a charge weight of 100 and 500 kg TNT when placed at a 30 m distance from the origin of the explosion using analysis software Sap 2000 [6]. Athira Sathyan et al. researched the dynamic behaviour of crew modules made of metallic isogrid and metallic sandwiches under blast loading. Using the software Abaqus linear dynamic analysis was performed [7].

Sarita Singla et al. studied the blast loading calculations for a multi-story framed structure. This study computed blast pressures for a multi-storey framed building for 100,200,300 kg TNT charge weight of ground blast and 10,20,30-meter standoff distances [8]. Anthugari Vimala and ramacharla Pradeep Kumar studied the aspect ratio's influence on the damage of the building subjected to seismic loading. This study uses nonlinear pushover analysis to know the damage, hing pattern, and displacement [9].Siwinski, Jarosław, and A. Stolarski conducted a study using Abaqus to find out the response to the blast. Two types of buildings are based on concrete properties, steel rebar properties, and the effective reinforcement ratio [10]. Sanjay Kumar sadh and Umesh pendharkar studied how the aspect ratio and configuration affect the performance of seismic loads for a multi-stored RCC structure by response spectrum method [11]. Priyanka Soni et al. studied the importance of shear walls and their location. These three types of multi-storey buildings (G+10,20,26) were considered. Storey drift, base shear, and lateral displacement parameters are studied. Analysis was carried out in Staad pro software [12]. Akhila Ramanujan et al. have studied an analysis on a wall subjected to air blast with GFRP and without GFRP wall using ANSYS and compared the performance upon blast for four different charge weights at 1.7 and 2 meters from the blast wall [13]. M. D. Chiranjeevi and J. Simon studied to prevent blast loading on structures, became acquainted with design methods used in accordance with UFC guidelines, and incorporated an alternate path method for design by accepting the positive phase into account for the analysis [29]. Parvin, Azadeh, et al. studied finite element analysis of multi-story frame structures subjected to blast loadings by Nonlinear dynamic analysis and compared it to nonlinear static analysis [15]. Tanneru sreevalli et al., Using the software E-tabs, a study was carried out to evaluate the impact of shear wall area on the floor area of a 30-story building. Static and Response spectrum analyses are carried out according to IS 1893:2002 [16]. Kumar M P and Rambabu K evaluated and derived the response to load variations and structural characteristics by considering a linear setback to dynamic disturbances such as earthquake and blast loading [17]. Janakkumar and Hitesh studied G+7 storey buildings with different shear wall configurations considered in zone-v seismic design for a medium type of soil and concluded that the shear wall at the periphery showed less period [18]. Kumar M P and Rambabu used Applied element method software to investigate how geometric RC space framed framework perform when exposed to seismic and impact loads [19]. Pravesh Tewari and Abhay Sharma studied the effect of blast loading on a 6-storey RCC building at a 30m standoff distance [20]. Sil A and Phukan D studied the characteristics of blast waves and the relationship between the parameters like scaled distance, phase duration, reflected overpressure, and incident overpressure. An empirical equation is derived considering the factors affecting the blast-resistant design, which could help predict the safe distances to minimise the blast effect on the structure depending on the type of blast [21]. M. Pavan Kumar and G.K. Chaitanya proposed a comprehensive system to analyse the blast, which addresses the collapsed part, inflexibility of flying debris, blockage, and the strength and integrity of the entire structure. This assessment has various operations, especially in furnishing guidelines for blast protection of RC structures [22]. Megha and Ramya studied the behaviour of buildings when affected by blast loads of 200,400 and 600 kg TNT intensity occurring at a distance of 20,40, and 60 meters [14]. Vangipuram et al. aimed to provide a better understanding of blast load analysis. For this s, simple and effective approach has been studied to reduce the complexity of blast load analysis and increase the efficiency of blast load analysis. Suggestions were given to improve the efficiency of members subjected to blast loading [24]. Priyawakode et al. have performed a study on the influence of response of lateral load developed by blast load in terms of peak deflections, bending stresses and normal stresses are determined and bridge pier performance under blast loading. [25]. Bharati and Sunita A study has been conducted to assess the effect of a 500 and 1000 kg TNT land surface blast on a multi-storey building at standoff distances of 5, 10, 15, 30, 40, and 60 m when seismically analysed and designed [26].

3. Methodology

For the study, a six-storied regular RC framed building (RFB) with different aspect ratios of (AR-1, 1.25, 1.5, 1.75 & 2) is considered. Throughout the study, each floor area of the building is kept constant (i.e., Floor area as 484 Square meters and Plot area as 500 Square meters). A blast load of intensity 2500 Kg TNT charge weight at a standoff distance of 10 meters was applied on all the buildings as mentioned above as a time history function using the software package SAP 2000 v20. Blast parameters are evaluated using technical manual TM-5-1300 [27]. Parameters like lateral displacement and acceleration of all the buildings are observed to know the blast response of the considered building with different aspect ratios. Different case studies analysed for this work are explained in table 1.0. Geometric details of the considered building for the study are shown in figure 1.0.

3.1. Properties of Structural Elements

Following are the cross-section details of various structural components of the considered building.

Plinth beam : 230 x 230 mm
Floor beam : 230 x 450 mm
Column : 450 x 450 mm
Slab: 150 mm

3.2 Materials

Grade of concrete : M30
Grade of steel : Fe500

3.3 Blast Load

Charge weight : 2500 kg TNT
Standoff distance : 10 meters
The location of the blast load applied to the structure is shown in figure 2.

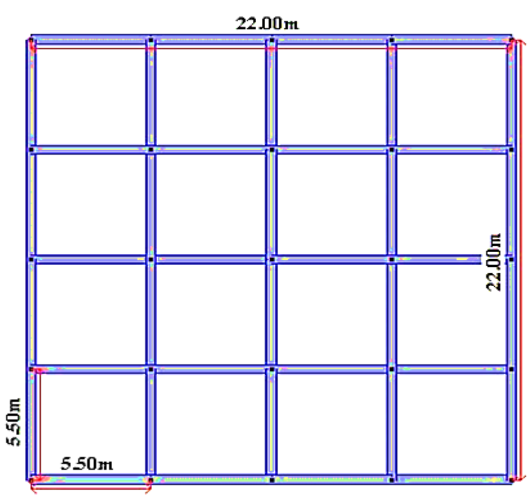
Blast load positive phase parameters are evaluated from technical manual TM-5-1300. Typical blast load calculations are discussed in clause 4.0. Blast load parameters for a charge weight of 2500kg TNT at a standoff distance of 10m are presented in table 2.0.

Table 1. Case Studies

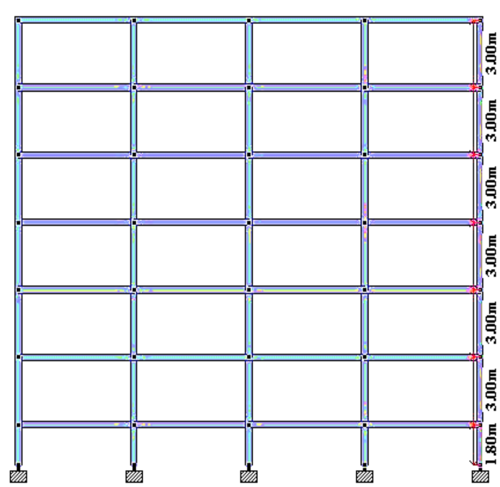
S.No.	Designation of Building	Description of Building	Size of Building (m x m)
1	RFB – AR – 1.00	Regular Frame Building with Aspect Ratio – 1.00	22.00 x 22.00
2	RFB – AR – 1.25	Regular Frame Building with Aspect Ratio – 1.25	24.59 x 19.67
3	RFB – AR – 1.50	Regular Frame Building with Aspect Ratio – 1.50	26.94 x 17.94
4	RFB – AR – 1.75	Regular Frame Building with Aspect Ratio – 1.75	29.10 x 16.63
5	RFB – AR – 2.00	Regular Frame Building with Aspect Ratio – 2.00	31.11 x 15.55

Table 2. Blast load parameters for charge weight of 2500kg TNT at a standoff distance of 10m

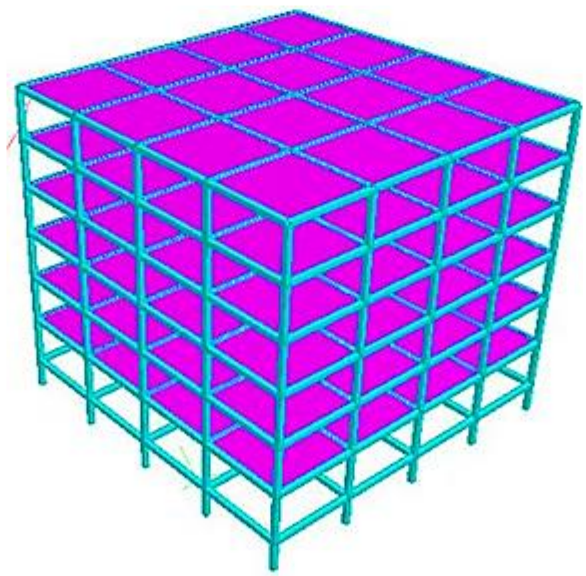
Location	t_A(ms)	i_s(ms)	t_{of}(ms)	t_{A+} t_{of} (ms)	P_r (Mpa)	P_r (kN/m^2)
Plinth	3.53	372.91	2.06	5.60	14.22	14220
1st floor	3.97	384.39	2.30	6.28	14.77	14779
2nd floor	4.77	422.23	3.15	7.92	10.03	10034
3rd floor	6.24	458.23	4.58	10.81	7.54	7548
4th floor	8.13	427.67	5.88	14.01	3.95	3955
5th floor	10.71	383.86	7.29	17.99	1.84	1848
6th floor	13.69	341.64	8.76	22.45	1.02	1028



(a) Plan



(b) Elevation



(c) Isometric view

Fig. 1 Geometric views of RFB – AR-1.00

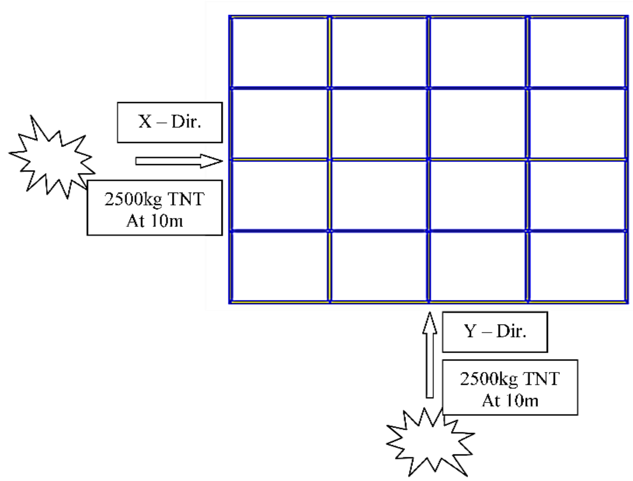


Fig. 2 Location of Blast Load applied in both directions

3.4 Analysis

Nonlinear dynamic analysis was performed on regular framed buildings with different aspect ratios to study the blast response using the software package SAP 2000 v20.

4. Estimation of Blast loads

4.1 Blast Phenomena

When an explosion happens, the initial pressure, which is ambient pressure (P_o), instantly rises to a peak pressure (P_{so}) at the time of arrival (T_a). After attaining the peak value, the pressure decreases at an uncontrolled rate until it reaches ambient pressure, called the positive phase duration. Post this positive duration; the pressure decreases, then the ambient pressure, called the negative phase duration. The negative phase duration is longer than the positive phase duration and is ignored in the design as their values are small. Structures are subjected to suction force in a negative phase. Minimum pressure is denoted by (P_{so-}) and its corresponding time duration as (T_{o-}). If the overall performance of the structure is to be considered, pressures lower than ambient pressures are considered. Figure 3.0 shows the Ideal blast wave's pressure time history.

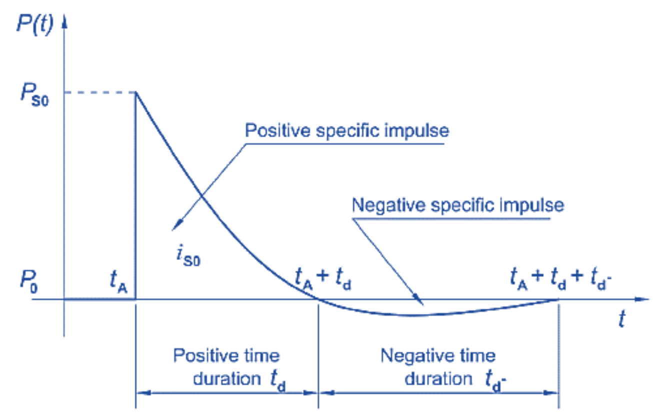


Fig. 3 Ideal blast wave's pressure time history curve [27]

4.2. Blast load calculation

Blast parameters are evaluated by using technical manual TM-5-1300. Typical blast load calculations at the plinth level of RFB-AR-1.00 are discussed as follows.

Step 1:

Charge weight = 2500kg = 2500 x 2.205 =5512.5lbs

Range, R_G = 10m = 10 x 3.28 = 32.8ft

Step 2:

Determining free-blast wave parameters P_{so}, T_a and i_s from figure 2-1 of TM 5-1300.

Scaled ground distance, Z_G

$$Z_G = \frac{R_G}{W^{1/3}} = \frac{32.8}{5512.5^{1/3}} = 1.86 \frac{\text{ft}}{\text{lb}^{1/3}}$$

Peak positive incident pressure, P_{so} = 361.48

Time of arrival of blast load, T_a

$$\frac{t_a}{w^{1/3}} = 0.2$$

T_a = 3.53 ms

Unit positive incident impulse, i_s

$$\frac{i_s}{W^{1/3}} = 21.11$$

i_s = 372.91 psi-ms

Fictitious positive phase pressure duration, t_{of}

$$t_{of} = 2\,x\,\frac{i_s}{P_{so}}$$

$$= 2x\,\frac{372.91}{361.48}$$

= 2.06ms

Step 3:
The Angle of Incidence, $\alpha = 0^0$

Determining reflected pressure coefficient ($C_{r\alpha}$) from figure 2-193 of TM 5-1300.

$C_{r\alpha} = 5.71$

Peak reflected pressure at an angle of incidence, $P_{r\alpha}$

$P_{r\alpha} = C_{r\alpha} \times P_{so}$
$= 5.71 \times 361.48$
$= 2064.05$ psi
$= 2064.05 \times 0.0069$
$= 14.22$ MPa

5. Results and Discussions

Based on the study's results, the building's response, i.e., variation of lateral displacement and acceleration to time, is plotted at different story levels. The comparison was made among all the considered cases to find out the less affected structure during an explosion.

5.1. Blast Response

5.1.1. Lateral Displacement Variation

Figures 3 to 7 show the variation of lateral displacement for the time at various story levels for all the considered models.

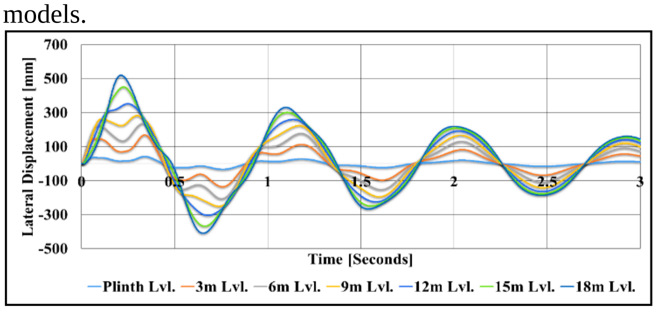
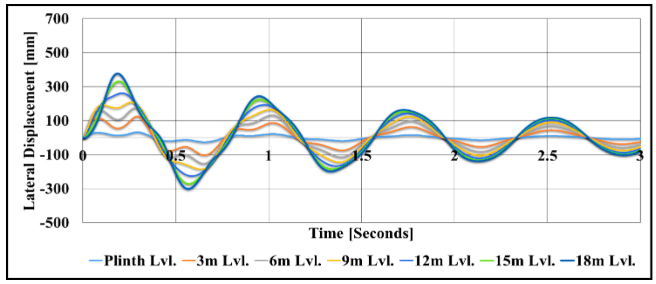
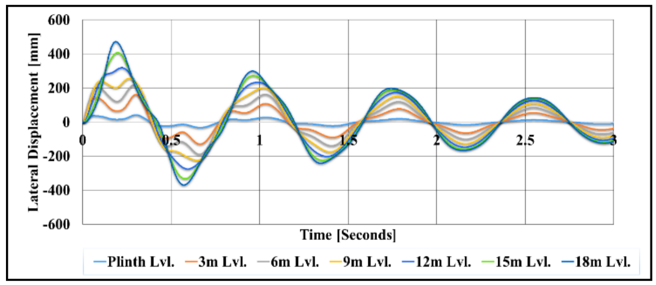


Fig. 4 Variation of Lateral displacement of RFB – AR -1.00

From figure 4, it was observed that the maximum positive displacement of 520.22mm occurred at 0.0213 seconds, and the negative displacement of 409.26mm at 0.6525 seconds corresponds to the roof level of RFB-AR-1.00.



(a) X- direction

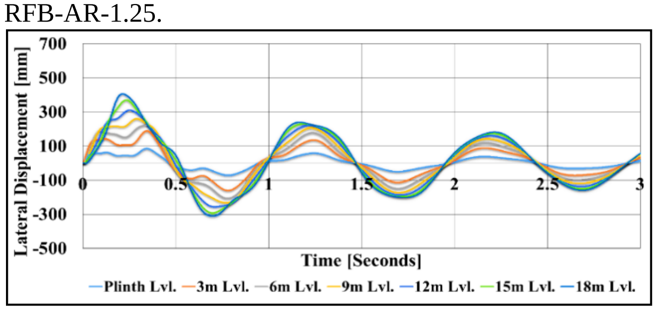


(b) Y - direction

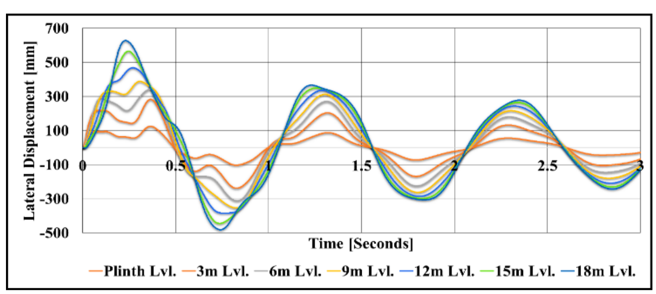
Fig. 5 Variation of Lateral displacement of RFB – AR -1.25

Figure 5(a) shows that the maximum positive displacement of 377.41 mm occurred at 0.1875 seconds and a negative displacement of 301.18mm at 0.567 seconds in the X-direction corresponding to the roof level of RFB-AR-1.25.

From figure 5(b), it was observed that the maximum positive displacement of 472.01mm occurred at 0.1875 seconds and negative displacement of 369.72mm at0.5715 seconds in the Y-direction corresponding to the roof level of RFB-AR-1.25.



(a)X- direction

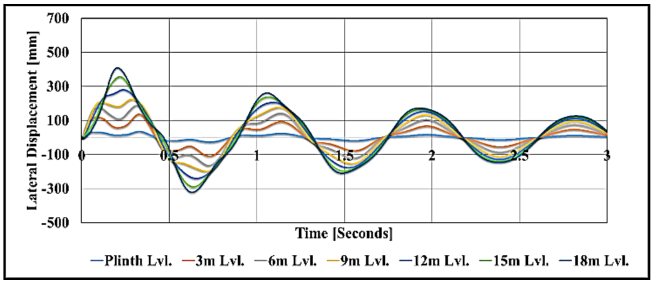


(b)Y- direction

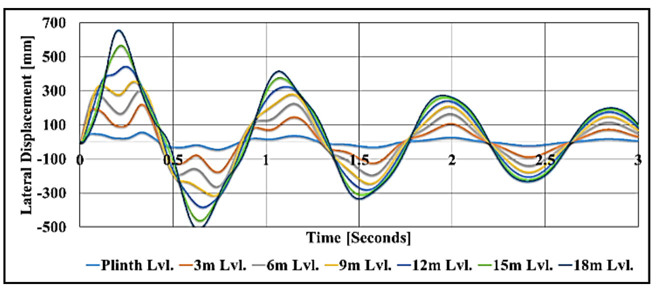
Fig. 6 Variation of Lateral displacement of RFB – AR -1.50

Figure 6(a) shows that the maximum positive displacement of 406mm occurred at 0.2145 seconds and a negative displacement of 310.07 mm at 0.699seconds in the X-direction corresponding to the roof level of RFB-AR-1.50.

From figure 6(b), it was observed that the maximum positive displacement of627.87mm occurred at0.231 seconds and negative displacement of 480.73mm at 0.741 seconds in the Y-direction corresponding to the roof level of RFB-AR-1.50.



(a) X- direction

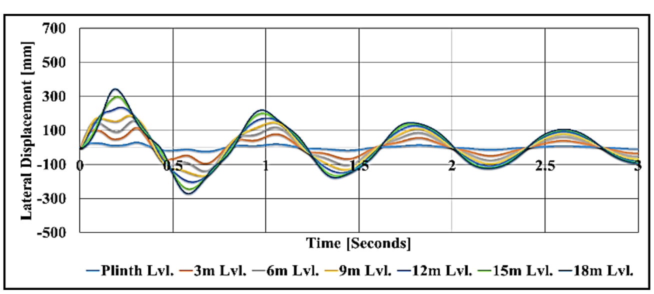


(b)Y- direction

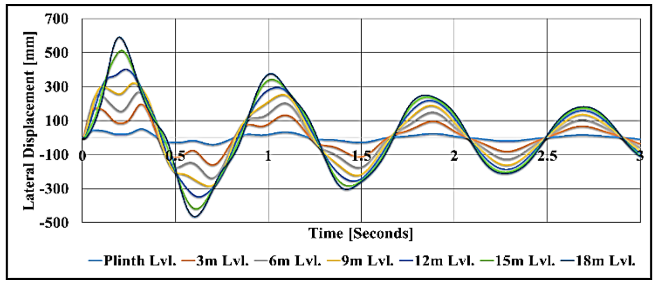
Fig.7 Variation of Lateral displacement of RFB – AR -1.75

From figure 7(a), it was observed that the maximum positive displacement of 408.33 mm occurred at 0.2055 seconds and a negative displacement of 322.23 mm at 0.63 seconds in the X-direction corresponding to the roof level of RFB-AR-1.75

From figure 7(b), it was observed that the maximum positive displacement of 655.99 mm occurred at 0.2085 seconds and a negative displacement of 512.13 mm at 0.6375 seconds in the Y-direction corresponding to the roof level of RFB-AR-1.75.



(a) X- direction



(b)Y- direction

Fig. 8 Variation of Lateral displacement of RFB – AR -2.00

From figure 8(a), it was observed that the maximum positive displacement of343.22 mm occurred at 0.1905 seconds and negative displacement of 271.26mmat 0.5835 seconds in the X-direction corresponding to the roof level of RFB-AR-2.00.

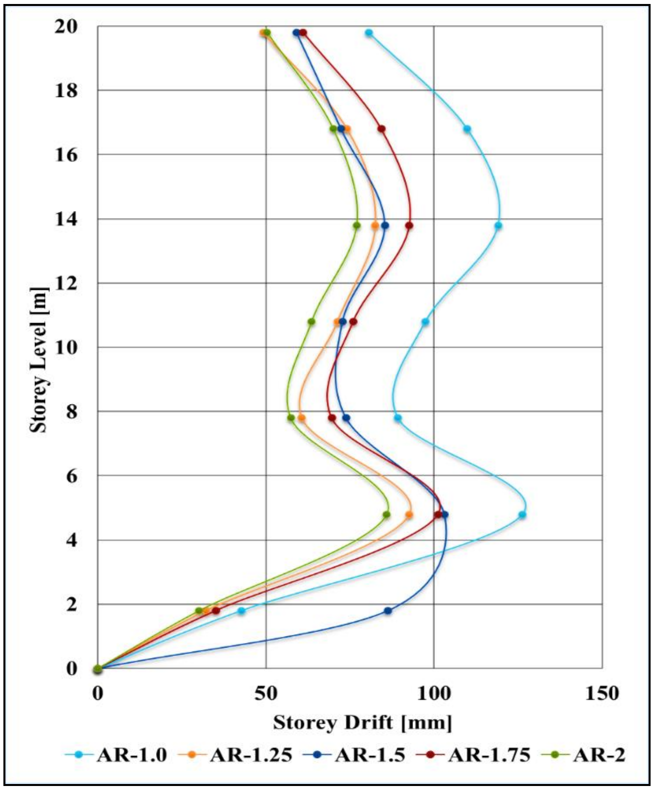
From figure 8(b), it was observed that the maximum positive displacement of591.36mm occurred at 0.1995 seconds and negative displacement of 464.25mm at 0.6045seconds in the Y-direction corresponding to the roof level of RFB-AR-2.00.

5.1.2. Inter-Storey Drift (ISD)

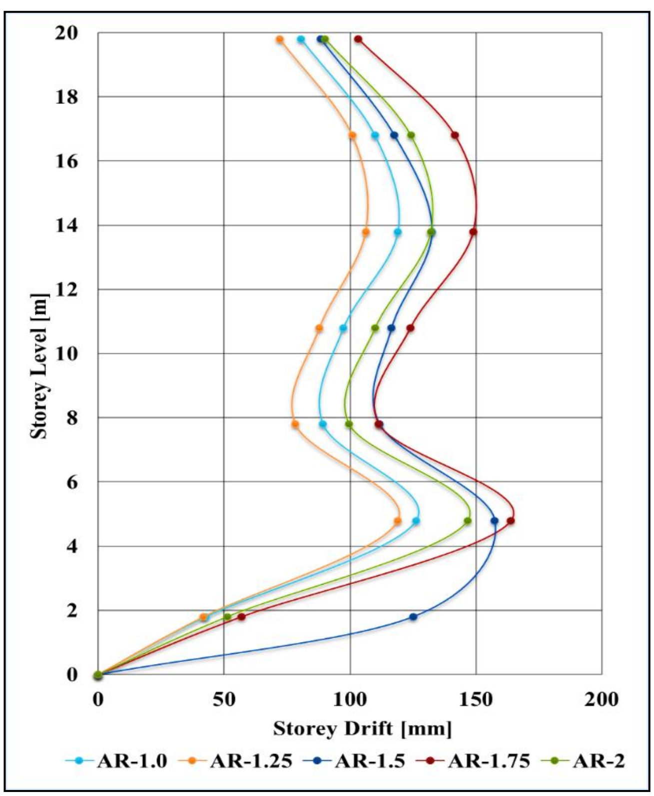
Inter-storey drift variation at different storey levels of all the considered models against blast load in X and Y directions is shown in figure 8. Figures 8a and 8b show that the maximum inter-storey drift is observed at the 3m level for all the considered aspect ratios of the building in both X & Y directions of explosion.

Among all the building models with various aspect ratios, the building with an aspect ratio of 1.0 (RFB-AR-1.00) has produced a maximum inter-storey drift in the X direction of the explosion. Reduction in inter-storey drift by 32% is observed n RFB-AR-2.0 when compared to RFB-AR-1 in the X direction of the explosion. Simultaneously, observed an increase in the inter-storey drift of 25% in RFB-AR-2.0 when compared to RFB-AR-1 in the Y direction of the explosion. Unlike a typical RC framed structure, maximum inter-storey drift observes at the 3m level in all the considered building models. It is a clear understanding from any building; it acts like a cantilever having rigidity at the bottom and free at the top.

The influence of rigidity would be more significant at lower stories; it will be lesser when going towards higher stories. For any building subjected to lateral loads, the building will notice greater drifts at higher storey levels. However, in this case (i.e. structure subjected to Surface blast loading) observed, maximum storey response at a lower level as that portion of the structure was the nearest point to blast and hence was subjected to higher blast pressure. By its predominant cantilever behaviour of the structure, noticed the next maximum response at top storey levels.



(a) X- direction



(b) Y- direction

Fig. 9 Variation of Inter Storey Drift (ISD) of the structure against Blast Load

5.1.3. Variation of Acceleration

Variations of Acceleration to time at different story levels of all the considered models are presented in figures 9 to 14.

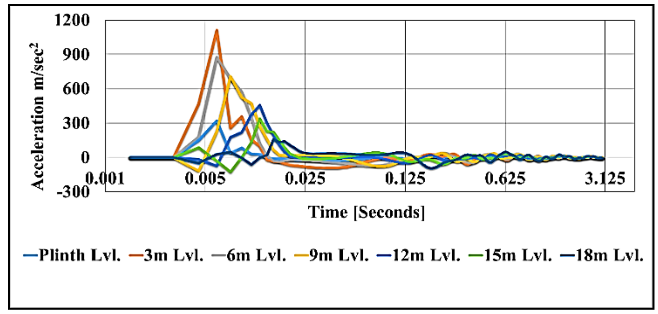
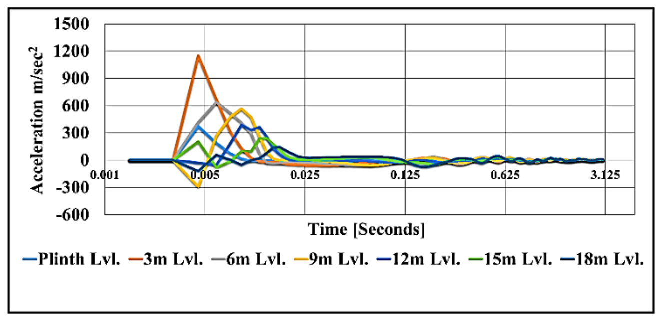
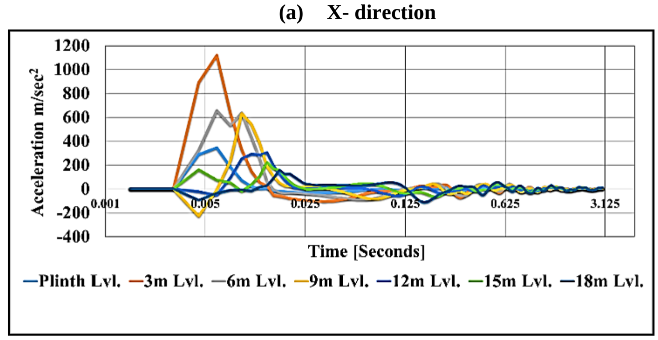


Fig. 10 Variation of Acceleration of RFB – AR -1.00

From figure 10, it was observed that a maximum acceleration of 1110.664 m/sec^2 occurred at 0.006 seconds corresponding to 3 meter level of RFB-AR-1.00.



(a) X- direction



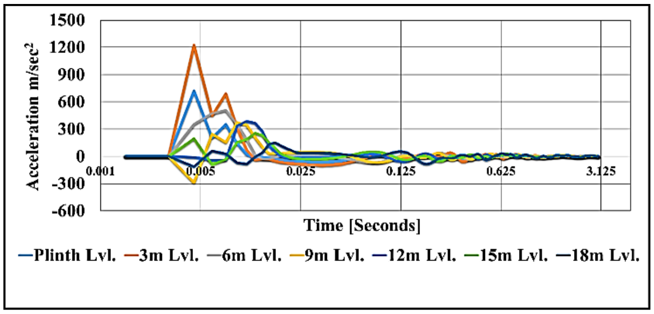
(b) Y- direction

Fig. 11 Variation of Acceleration of RFB – AR -1.25

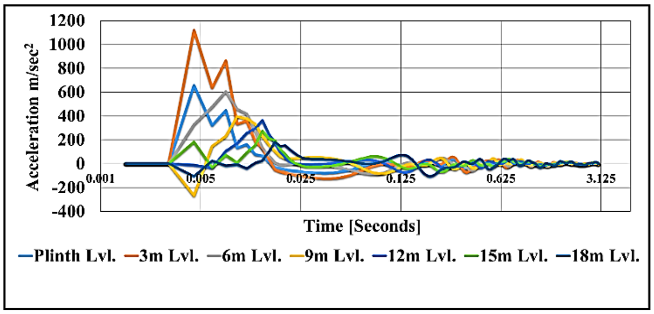
Figure 11(a) shows that a maximum acceleration of 1150.277m/sec^2 occurred at 0.0045 seconds in the X-direction corresponding to the 3-meter level of RFB-AR-1.25.

From figure 11(b), it was observed that a maximum acceleration of 1119.99m/sec^2 occurred at 0.006 seconds in the Y-direction corresponding to the 3-meter level of RFB-AR-1.25.

Figure 12(a) shows that a maximum acceleration of 1222.552 m/sec^2 is obtained at 0.0045 seconds in the X-direction corresponding to the 3-meter level of RFB-AR-1.50.



(a)X-direction

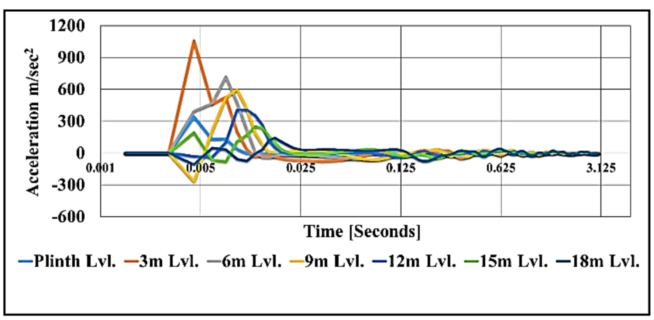


(b) Y-direction

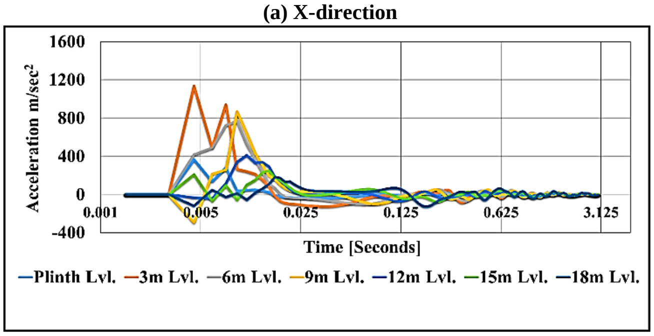
Fig.12 Variation of Acceleration of RFB – AR -1.50

Figure 12(b) shows that a maximum acceleration of 1120.331m/sec^2 is obtained at 0.0045seconds in the Y-direction corresponding to the 3-meter level of RFB-AR-1.50.

Figure 13(a) shows that a maximum acceleration of 1058.615 m/sec^2 occurred at 0.0045 seconds in the X-direction corresponding to the 3-meter level of RFB-AR-1.75.

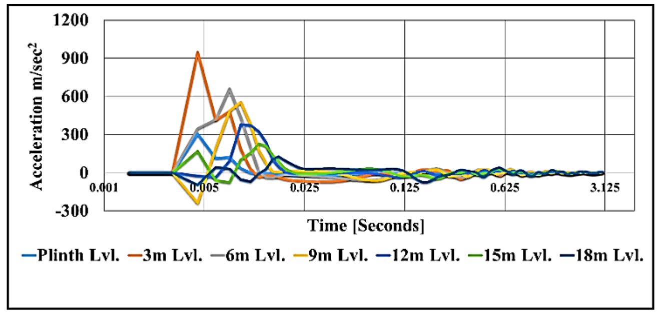


(a) X-direction

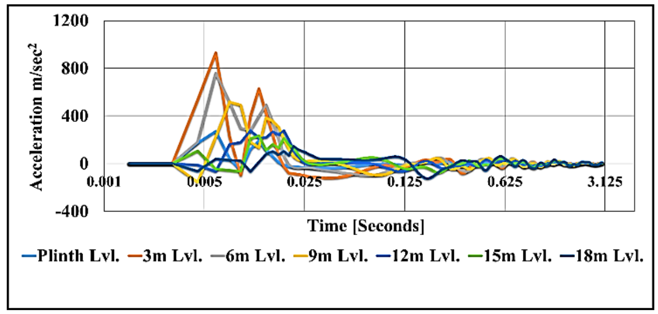


(b) Y-direction

Fig. 13 Variation of Acceleration of RFB – AR -1.75



(a)X-direction



(b) Y-direction

Fig. 14 Variation of Acceleration of RFB – AR -2.00

From figure 13(b), it was observed that a maximum acceleration of 1135.124m/sec^2 occurred at 0.0045seconds in the Y-direction, corresponding to a 3-meter level of RFB-AR-1.75.

Figure 14(a) shows that a maximum acceleration of 1058.615m/sec^2 occurred at 0.0045 seconds in the X-direction corresponding to the 3-meter level of RFB-AR-2.00.

From figure 14(b), it was observed that a maximum acceleration of 931.11m/sec^2 occurred at 0.006seconds in the Y-direction, corresponding to a 3-meter level of RFB-AR-2.00.

5.1.4. Energy Absorption

The measure of energy absorbed by the structure during blast wave impact is studied to know the damaging impact on structural elements of the building. The energy absorbed by the building due to blast load calculates using $\int a^2 dt$. This intensity form represents the building's overall duration, amplitude, and frequency change due to the blast. Figures 14 and 15 observed a rapid change in energy absorption at initial time steps, with almost 75% of the total energy absorbed by the structure for a time period of 3 seconds observed within 10-time steps (i.e., 10 x 0.0015 = 0.015 Seconds), later there is slight variation occurs gradually of all considered buildings in both X and Y direction of the explosion. In the X-direction of the explosion, a building with aspect ratios 1.5 and 2 has produced maximum and minimum energy absorption, respectively. Simultaneously, building with aspect ratios 1.75 and 1.0 has produced maximum and minimum energy absorption, respectively, for an explosion in the Y - direction.

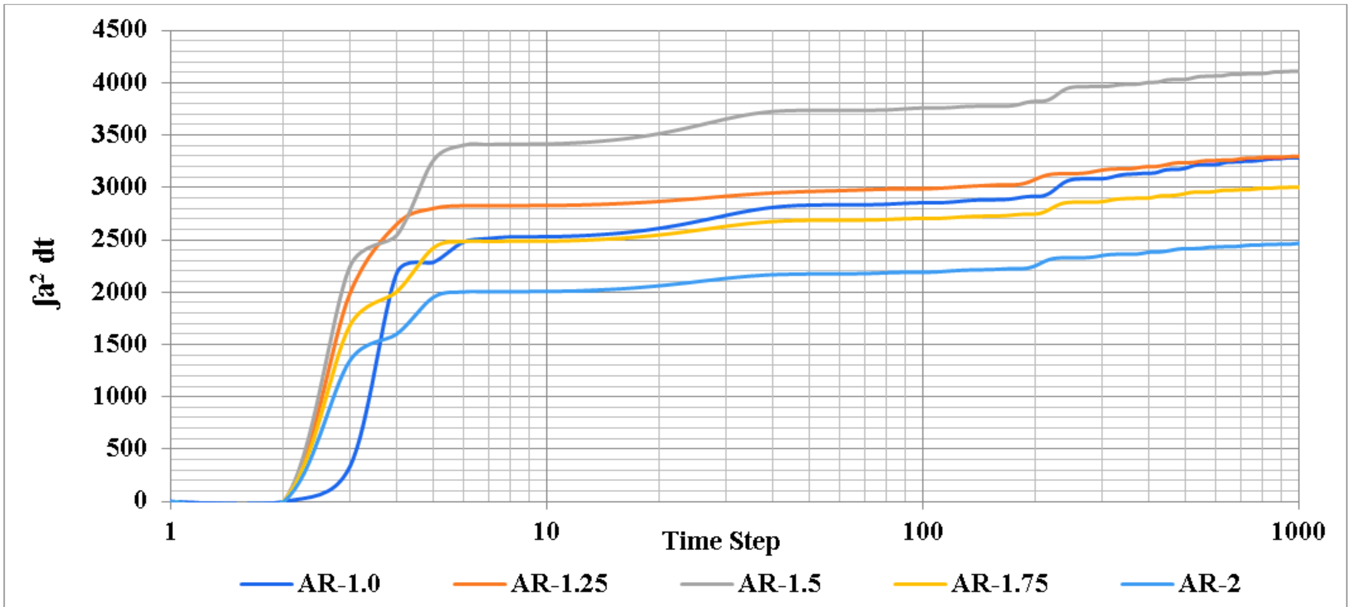


Fig. 15 Variation of energy Absorption [∫a²dt] of all the considered buildings subjected to X-direction explosion

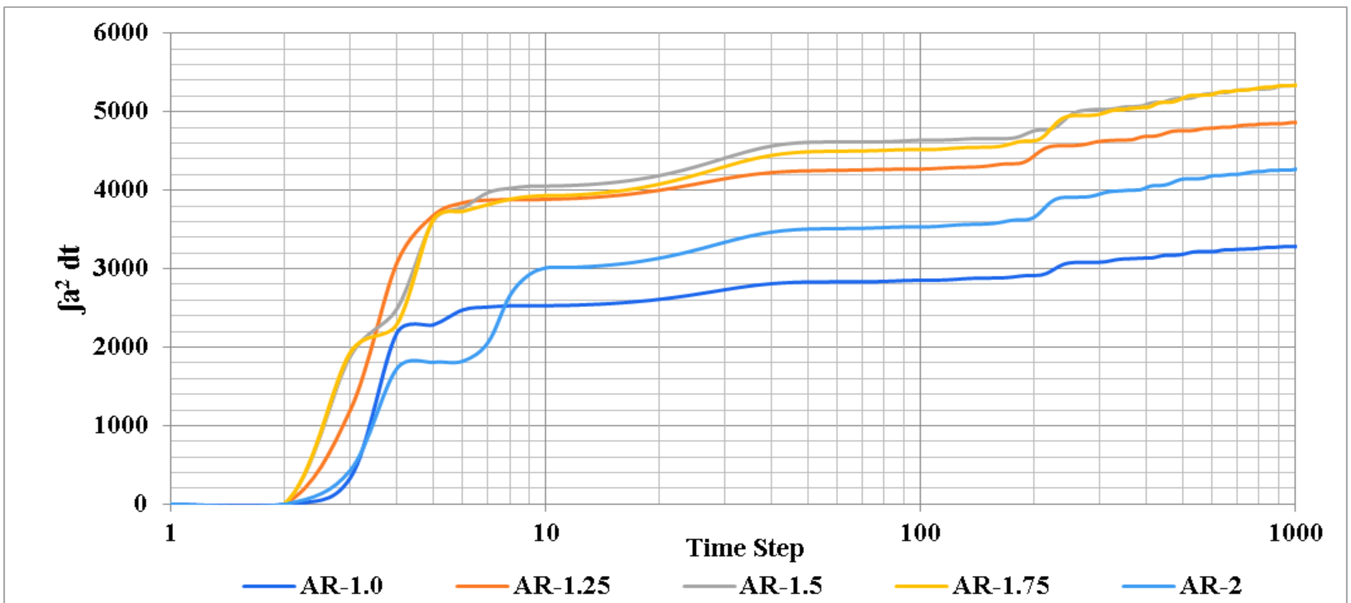


Fig. 16 Variation of energy Absorption [∫a²dt] of all the considered buildings subjected to Y- Y-direction explosion

6. Conclusion

Nonlinear dynamic analysis was performed on regular framed buildings with different aspect ratios to study the blast response. Following are the major conclusions observed from the study.

1. Building subjected to X - a direction explosion, lateral deformation decreases from 520mm to 343mm when the aspect ratio increases from 1 to 2. Whereas for Y - Y-direction explosion, lateral deformation increases from 520 mm to 591 mm when the aspect ratio increases from 1 to 2.
2. Building subjected to X - direction explosion, acceleration decreases from 1110 to 946 m/sec^2 when the aspect ratio increases from 1 to 2. Whereas for Y - direction explosion, acceleration decreases from 1110 to 931 m/sec^2 when the aspect ratio increases from 1 to 2.
3. A maximum inter-storey drift of the building subjected to X - a direction explosion decreases from 126 to 85 mm when the aspect ratio increases from 1 to 2. For Y - the direction explosion, it increases from 126 to 146 mm when the aspect ratio increases from 1 to 2.

4. Reduction in inter-storey drift by 32% is observed in RFB-AR-2.0 when compared to RFB-AR-1 in the X direction of explosion simultaneously observed an increase in an inter-storey drift of 25% in RFB-AR-2.0 when compared to RFB-AR-1 in Y direction of the explosion.

5. In all the case studies, rapid change in energy absorption was found at initial time steps, with almost 75% of the total energy absorbed by the structure for a time period of 3 seconds observed within 10-time steps.

6. In X - the direction of the explosion, building with aspect ratios 1.5 and 2 have produced maximum and minimum energy absorption, respectively. Simultaneously, building with aspect ratios 1.75 and 1.0 produced maximum and minimum energy absorption for the explosion in Y-direction.

7. The study concluded that a building with an aspect ratio of 2.00 is less affected by the geometric model subjected to surface explosion when compared to other building models.

8. The geometry and orientation of a building play an important role in controlling various parameters like lateral displacement and acceleration of the building.

References

[1] Z. Koccaz, F. Sutcu, and N. Torunbalci, "Architectural and Structural Design," *14th World Conference on Earthquake Engineering, Beijing, China*, pp. 8, 2008.

[2] T.P. Nguyen, M.T. Tran, "Response of Vertical Wall Structures under Blast Loading by Dynamic Analysis," *Procedia Engineering*, vol. 14, pp. 3308–3316, 2011. Crossref, http://doi.org/10.1016/j.proeng.2011.07.418

[3] T. Ngo, P. Mendis, A. Gupta, and J. Ramsay, "Blast Loading and Blast Effects on Structures – An Overview," *Electronic Journal of Structural Engineering*, no. 1, pp. 76–91, 2007. Crossref, http://doi.org/10.56748/ejse.671

[4] H. L. Murphy, "Blast Loading on Structures," *Journal of the Structural Division*, vol. 84, no. 7, 1958. Doi: 10.1061/jsdeag.0000297

[5] Jayashree S.M., Bharatwaj R. Rakul, Santhi M. Helen, "Dynamic Response of a Space Framed Structure Subjected to Blast Load," *International Journal of Civil and Structural Engineering*, vol. 4, no. 1, pp: 98-105, 2013. Crossref, http://doi.org/10.6088/ijcser.201304010010

[6] Q. Kashif and M. B. Varma, "Effect of Blast on G + 4 RCC Frame Structure," *The International Journal of Emerging Technology and Advanced Engineering*, vol. 4, no. 11, pp. 145–149, 2014.

[7] Athira Sathyan, A P Beena, Dr. S B Tiwari, Ranjan Abraham, "Comparison of Dynamic Behaviour of Structures Subjected to Blast Loads," *International Journal of Engineering Trends and Technology*, vol. 28, no. 9, pp. 469-472, 2015.

[8] Sarita Singla, Pankaj Singla, Anmol Singla, "Computation of Blast Loading for a Multi Storeyed Framed Building," *International Journal of Research in Engineering and Technology*, vol. 4, no. 2, pp. 759–766, 2015. Crossref, http://doi.org/10.15623/ijret.2015.0402105

[9] Anthugari Vimala and Ramancharla Pradeep Kumar, "Effects of Aspect Ratio on Nonlinear Seismic Performance of RC Buildings," *International Journal of Research in Engineering and Technology*,vol. 4, pp. 297-304, 2015.

[10] Siwiński J, Stolarski A, "Modeling of Buildings Behavior Under Blast Load," In Awrejcewicz, J. (eds) *Dynamical Systems: Modelling, Springer Proceedings in Mathematics & Statistics, Springer*, Cham, vol 181, pp. 341-352, 2016. Crossref, https://doi.org/10.1007/978-3-319-42402-6_27

[11] Sanjay Kumar Sadh and Umesh Pendharkar, "Influence of Aspect Ratio & Plan Configurations on Seismic Performance of Multistoreyed Regular R.C.C. Buildings: An Evaluation by Response Spectrum Analysis," *International Research Journal of Engineering and Technology*, vol. 3, no. 1, pp. 293-299, 2016.

[12] Ms. PriyankaSoni, Mr. PurushottamLalTamrakar, VikkyKumhar, "Structural Analysis of Multistory Building of Different Shear Walls Location and Heights," *International Journal of Engineering Trends and Technology*, vol. 32, no. 1, pp. 50-57, 2016. Crossref, http://doi.org/10.14445/22315381/IJETT-V32P210

[13] AkhilaRamanujan, SreedeviLekshmi, "Comparative Study on the Analysis of Blast Wall with and without GFRP using ANSYS", *International Journal of Science and Research (IJSR)*, vol. 5, no. 7, pp: 864 – 870, 2016.

[14] Megha S. M, Ramya K, "Analysis of Multi-Storey RC Building Subjected To Blast Load Using Time History Method," *International Journal of Innovative Science and Research Technology*,vol. 4, no. 6, pp. 556-562, 2019.

[15] Parvin, Azadeh, Khandel, Omid& Crozier, David and Raad Janet, "Collapse Analysis of Concrete Frame Structures Subjected to Extreme Loading", in Conference: SMAR 2017, the *Fourth International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures*, 2017.

[16] Tanneeru Sreevalli, N.Harika Priya, "Effect of Shear Wall Area on Seismic Behavior of Multistoried Building Tube in Tube Structure," *International Journal of Engineering Trends and Technology*, vol. 44, no. 4, pp. 202-210, 2017. Crossref, http://doi.org/10.14445/22315381/IJETT-V44P240

[17] Kumar M. P, Rambabu K, "Performance of RC Space Frame with Vertical Setback Subjected to Seismic and Blast Load Using Applied Element Method," *Disaster Advances*, vol. 10, no. 5, pp. 1–13, 2017.

[18] J. M. Mehta and H. K. Dhameliya, "Comparative Study on Lateral Load Resisting System in High-Rise Building using ETABS," *International Journal of Engineering Trends and Technology*, vol. 47, no. 2, pp. 115–117, 2017. Crossref, http://doi.org/10.14445/22315381/IJETT-V47P219.

[19] Kumar M. P, Rambabu K, "Response of Regular RC Space Frame Subjected to Seismic and Blast Load Using Applied Element Method," *Disaster Advances*, vol. 11, no. 7, pp. 17-28, 2018.

[20] P. Tewari and Abhay Sharma, "Effects of Blast Loading on Building Frames," *International Research Journal of Engineering and Technology,* vol. 5, no. 5, pp. 4063–4069, 2018.

[21] Sil A, and Phukan D, "Quantification and Analysis of Air Blast Load Propagation Characteristics on Structures," *Journal of Building Pathology and Rehabilitation,* vol. 4**,** no. 24, 2019. Crossref, https://doi.org/10.1007/s41024-019-0063-7

[22] Kumar, M Pavan & Krishna, Chaitanya, "Collapse Analysis of R.C Buildings Subjected to Blast Load Using AEM," *Blast Analysis of RC Buildings*, 2019.

[23] Vaneeta Devi, Deepak Chauhan, Neeraj Kumar Tiwari, Sunil Kumar, Subir Kumar Sharma, SanjeevSuman, Sandeep Gupta, "Seismic Analysis of R-C Multi-Storey Building with Various Lateral Load Resisting Systems*," SSRG International Journal of Civil Engineering,* vol. 9, no. 3, pp. 30-35, 2022. Crossref, https://doi.org/10.14445/23488352/IJCE-V9I3P104

[24] Vangipuram B, Sharief Md A. J, Sandeep B. B, Baraik S, "Behavior of Reinforced Concrete Structural Members Under the Influence of Implicit Blast Loading," *International Journal of Civil Engineering and Technology,* vol. 10, no. 7, pp. 349–358, 2019.

[25] Priyawakode, D. H. Tupe, G. R. Gandhe, “Blast Load Analysis on Bridge Subjected to Various Standoff Distance,” *International Journal of Engineering Research & Technology,* vol. 9, no. 7, 2020. Crossref, https://doi.org/10.17577/IJERTV9IS070312

[26] Tolani S, Bharti S. D, Shrimali M. K, & Datta T. K, “Effect of Surface Blast on Multistory Buildings,” Journal of Performance of Constructed Facilities,” vol. 34, no. 2, 2020. Crossref, https://doi.org/10.1061/(asce)cf.1943-5509.0001415

[27] U.S. Depts. of the Army, Navy, and Air Force, "Structures to Resist the Effects of Accidental Explosions," TM5-1300, Washington, DC,1990.

[28] Trajkovski, Jovan Kunc, Robert Perenda, Jasenko and Prebil Ivan, "Minimum Mesh Design Criteria for Blast Wave Development and Structural Response – MMALE Method," *Latin American Journal of Solids and Structure,* vol. 11, no. 11, 1999. Crossref, https://doi.org/10.1590/S1679-78252014001100006

[29] Chiranjeevi M.D, & Simon J, "Analysis of Reinforced Concrete 3d Frame under Blast Loading and Check for Progressive Collapse," *Indian Journal of Science and Technology,* vol. 9, no. 30, pp. 1-6, 2016. Crossref, https://doi.org/10.17485/ijst/2016/v9i30/99232