Study on the Behavior of Single Storied R/C Framed Structure under Blast Loading and Seismic Excitation

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Abstract – *The study proposes to analyze the behavior or the performance of a single storied R/C framed structure under blast loading and critical seismic excitation on community like low-rise structure in overall sense. With limited scope, system with symmetric configuration has been proposed herein to give an idea for the protection, like the distance of fencing to be constructed to protect the structure and minimize the losses. The non-linear equation of motion associated with the structural system proposed to analyze in time domain using Newmark's β-γ scheme with the consideration of average acceleration over each incremental time step using ABAQUS. Modification Newton-Raphson technique is used to perform iteration in each time increment. Effect of blast is taken as time varying external force, which can be determined from the product of area under the influence and blast pressure. In this study after considering a fixed standard change weight of 1 Ton and by varying stand-off distance, it was found that at certain distance the building can sustain the pressure exerted by the blast wave and the displacement comes out such that the damage can be minimized by providing a boundary wall at a distance of 45 m from the idealized structure. As far as the earthquake is concerned, it may create some damage, which is repairable and can be avoided if proper seismic design measure is taken during design phase.*

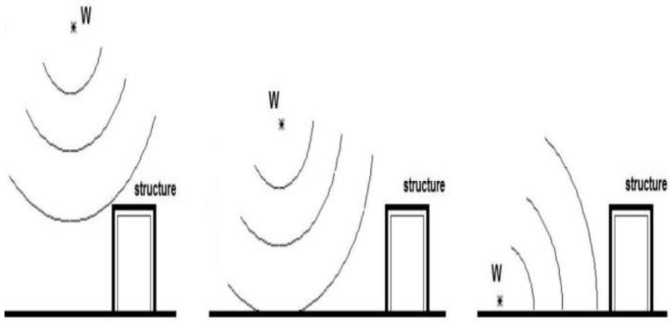
***Key Words*: Blast Loading, Stand-off Distance, Charge Weight, Low-Rise Structure, SDOF System.**

1. INTRODUCTION

The ever-increasing threats and attacks from terrorist organizations, lead to put an immense pressure for the study of blast effect on structures on very serious note. Though there are some guidelines regarding blast resistant design e.g.-(BIS 4991-1968) [1], such issues are not generally taken into account during routine design of low-rise building which are in generally designed with seismic protection. Whereas auditorium or community like structure, which are generally low-rise structure, may be a hotspot for attack as large public gathering occurs. Some important references are USA military publications, Army Technical Manual 5-1300 [2]. During an event of bombing or blast on ground surface, high peak ground acceleration (PGA can be up to 1000 g) and short duration is induced near the explosion, which is the positive phase of blast waves. However, such blast induced ground motions may not appear to cause much serious damages. Hence, seismic hazard is likely damaged the structures in the event of earthquake. In becomes very important to know that the physics of explosion and earthquake are not similar, both blast and seismic actions are design issues related to life safety in design aspect [3]. Blast loads are resulting from various types of explosives, generate pressure waves that impose sudden dynamic loading on structures, which can lead to failure of structures and loss of such precious life [4]. Conventionally designed structures normally are not designed to resist blast loads because the magnitudes of design loads are significantly lower than those produced explosions and conventional structures are susceptible to damage from explosions. A designer can take steps to better understand the potential threats and protect the occupants and assets in an uncertain environment [5]. With proper characterization of blast loading and dynamic material properties, reliable analysis and design of structures under blast loading can be achieved. There are various approaches in designing the structures and structural components under blast loading. Common design practice is the usage of simplified single degree-of-freedom (SDOF) approach [6-8]. Many scholar has used FEM analysis to assess the structural response of structure under blast loading. R. Jayasooriva [9] et. al. carried their work using SAP2000 to perform elastic analysis of a 10-storey building frame under blast loading. They have used LS DYNA in second phase to carry out a nonlinear elasto-plastic analysis of 3D sub frame considering strain rate effects. They studied the damage mechanism and the extent of damage to assess the residual strength capacity of key elements that can cause catastrophic failure of large sections of the building and propagate progressive collapse. Fu Feng [10] studied the robustness of tall building under blast loading. He conducted 3D finite element analysis on a 20-storey building using ABAQUS to study the real behavior under blast loading. Detonation of typical package bomb with charge weight of Kg was simulated on the 12^{th} floor. The blast loading effect was considered through a sudden removal of certain columns, ignoring the duration of the blast load affecting the structures. It was concluded that for the buildings are designed using available design guidance, a small scale blast such as the package bomb can hardly trigger with the collapse of the whole building. H. M. Elsanadedy et. al. [11] studied the progressive collapse of a typical multistoried steel framed structure in Riyadh, Kingdom of Saudi Arabia, due to blast attacks, using the finite element analysis package LS-DYNA. Different blast scenarios were considered by removing columns at different location in the ground floor. The results shown that the building may undergo progressive collapse, even for a charge weight of 500 Kg that can be easily carried in a small vehicle. They recommended strengthening of column is not enough for resisting the blast loads due to the possible blast scenarios, they suggested some structural modification such as adding diagonal braces or shear walls. Considering the outcome of research work of both R. Jayasooriva [9] and H. M. Elsanadedy [11], it can be concluded that both the power of explosives and locations of structural element are responsible for the response of framed structures subjected to blast loading, probably with the latter being more critical as well as the overall response considered [12-14]. In this consequence, the research proposed herein is an attempt to determine the numerical response of a seismically designed idealized SDOF solitary structure to blast loading. Later on, investigation [15-19] predicting of response on symmetric structure cross-sections such as T-beams, quadrangular plates and stiffened plates to dynamic loading is more explicitly. Response owing to large impact and distributed impulsive loading is attempted in this literature [20]. The response spectra based on exponential distribution of blast pressure is developed in this literature [21]. Despite great sophistication in the assessment techniques, there exists relative paucity of experimental work done is situated [22-28] and the overall response also estimated [29-32]. Very recent approaches to estimate the overall response due to blast effect on structural system carried out blast response explosion [33-37]. In this drawback, this research proposes an attempt to compare the numerical response of a seismically designed structures and a structure undergoing blast loads. Other than evolution of localized damage, this work aims to give the overall response of the structure, which may be preferable in the context of simplicity and to give an economical and realistic proposal to mitigate the effect of explosion in geometrically symmetric community like structure in terms various parameters such as standoff distance and charge weight (In terms of equivalent amount of TNT) may be useful for practical section.

2. OVERVIEW OF BLAST LOADING

A blast is a large-scale explosion with rapid and sudden release of energy. An explosion, which occurs due to volcanic eruption, energy released from failure of compressed gas cylinder such as LPG are classified as physical explosion. Nuclear explosion from catastrophic failure atomic nuclear power plant, energy is released from the formation of different atomic nuclei by redistribution of previous protons and neutrons within the interacting nuclei. While in chemical explosion, rapid explosion of fuel elements such as hydrogen atoms is the primary source of energy. In a same way materials for explosion can be classified according to their physical state. Solids explosives are primarily high explosives. They can also be classified on their sensitivity to ignition as a primary, secondary and tertiary explosives. Primary explosives (lead aside) can be easily detonated from a simple ignition of spark. Secondary explosives such as trinitrotoluene (TNT), dynamite are less sensitive to ignition and considerably more energy is required to initiate such explosives. Such explosives when detonated create shock waves (a.k.a. blast waves), which often results in widespread damage of to the surrounding. Blasting agents such as ammonium nitrite fuel oil (ANFO) is an example of tertiary explosive. Detonation of highly condensed explosives generates hot gases under pressure ranging from 10 GPa to 30 GPa with temperature varying from 30,000°C to 40,000°C [6]. As a result, a layer of blast wave forms in front of this gas volume containing most of the energy released by the explosion. Blast loads can also be classified depending upon the confinement as confinement and unconfined explosions. For confined explosions, three cases exist such as fully vented explosion, fully confined explosions and partially confined explosions. And for unconfined explosion, also exists three cases viz. free air burst explosion, air burst explosion and surface explosion Fig. 1. In free air burst, it is assumed that the blast waves expand outwards in radial direction from the center of the charge as a spherical and impinges directly onto the structure without any prior interaction with any obstacles. In case of airburst, here also explosive charge detonated in air but the spherical blast waves impinge onto the structure after having interacted with ground surface first. While in surface burst, it is detonated almost at ground surface, the blast wave immediately interacts with ground and then propagate hemi spherically outwards and impinges onto the structure [7].



a) Free air burst b) Air burst c) Surface burst

Figure-1: Types of unconfined explosion.

Therefore, every blast will generate blast wave that will propagate from blast point to nearby structure in a waveform reflected from the ground in the air and collide through the building structure in a phase of Mach stem, as seen in Fig. 1. After that, what we get by this explosive wave on structure is the general blast wave pressure-tie history.

3. EFFECTS OF BLAST ON STRUCTURES

A conventional explosion forms a spherical shock wave from the source and the shock front at ground surface from a contact structure is almost vertical. In addition, its' effective yield of this contact burst is around twice that of an equal explosion high in the air. The shock wave propagates in all direction from the point of burst with high intensity causing in time-dependent pressure and suctions effects at all points in its' way. Here blast wave instantaneously increases to a value of pressure above ambient atmospheric pressure, which is generally considered as 1 kg/cm^2 at mean sea level. This increase in value of pressure is referred as side-on over pressure that decays as a shock waves expands outward from the explosion source. At the time of reflection of incident blast wave from structure, a region of compressive air is created in the vicinity of structure. Subsequently, the surface of the structure applies an external force to each air molecule, which is sufficient to provide equal momentum in opposite direction by Newton's third law of motion. Then after a short time, the pressure behind the front drop below the ambient pressure as shown in Fig. 2.

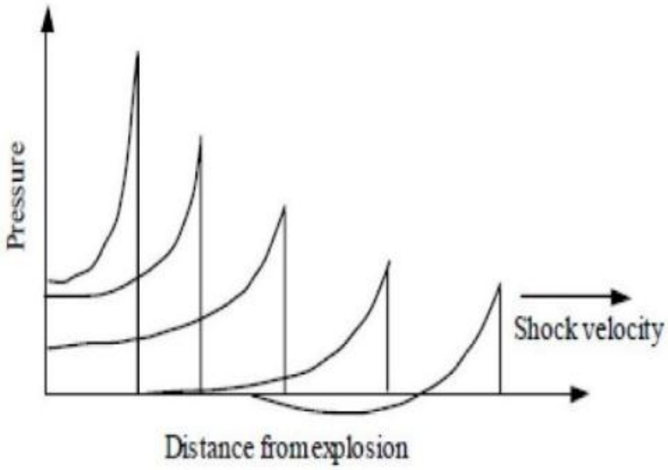


Figure-2: Blast wave propagation.

The shock wave consists of initial positive pressure phase followed by a negative phase (suction) at any point Fig. 3. The shock wave is accompanied by blast wind causing dynamic pressures due to drag effects on any obstacles in its' way. Due to diffraction of the wave at an obstructing surface reflected pressure is caused instantaneously which clears in a time depending on the extent of obstructing surface. At the surface encountered by the shock wave, the pressure rises almost instantaneously to peak values of side-on overpressure and dynamic pressure or their reflected pressure. The peak positive intensity quickly drops down to zero, the total duration of the positive phase being a few milliseconds. The maximum negative overpressure is much smaller than the peak positive overpressure, its limiting value being one atmosphere. However, the negative phase duration is two to five times as long as that of the positive phase.

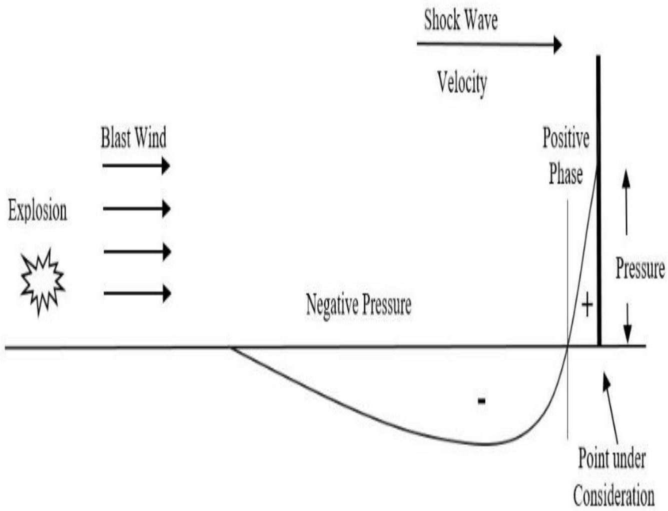


Figure-3: General wave pressure-time graph.

4. GENERAL PRINCIPLES OF BLAST LOADING

As in the case of normal loads, members subjected to blast pressures resist the applied force by means of internal stresses developed in them. However, the effective load due to blast, for which resistance should be developed in the member, depends upon the dynamic properties of the member itself. Longer the natural time period of the member smaller is the effective load for design [1].

- The duration of positive phase of blast is generally small as compared with the natural period of the structural elements, hence may be treated as an impulse problem.
- Considering the probability of occurrence of blast loading to be small, structures may be permitted to deform in the plastic range for economical design. Permitting plastic deformations increases the energy absorption and has the further advantage that the effective time period of the structural element is elongated, thereby reducing the effective load for its design.
- Most severe blast loading on any face of a structure is produced when the structure is oriented with the face normal to the direction of propagation of the shock front. However, for lack of known orientation of future explosion, every face of the structure shall be considered as a front face. When the blast field surrounds the structure, the difference of pressures on front and rear faces tends to tilt and overturn the structure as a whole.

As blast loads are dynamic in nature similar to earthquake and wind loads, there is a greater need for improving blast resisting construction. Few recent blast resistant construction around the world and technologies used such as:

1. Polymer composites as construction materials such as blast walls.
2. Blast proof masonry wall system and assessment of coupling effect using a TDOF model.
3. Ultra-high performance concrete and reactive powder concrete slabs.
4. Blast resistance of stiffened sandwich panels with closed cell aluminium foam.
5. Impulse resistant metal resistant sandwich plates.
6. Blast resistance of polyuria based composite materials, etc.

5. PROBLEM FORMULATION

A structure designed to resist blast loads are subjected to completely different type of loads than that are considered in conventional design. During an event of blast structures are hit with a rapidly moving shock wave. Blast wave loads the exposed surface of the structure and then the load is transmitted to other elements. Hence, the response of each individual element becomes important unlike the earthquake motion where the whole structural system is simultaneously causing inertia effects on all parts of a structure. For designing a structure, capable of resisting intense but short duration loads due to blast, members and joints are permitted to deflect and strain much greater than is allowed for usual static loads. This permitted deflection is ordinarily well into the plastic range of the material. Large amounts of energy are absorbed during this action, thus reducing the required design strength considerably below that required by conventional design within elastic range. Moreover, under higher rates of loading the strength developed by the material, increases with the rate of loading, and may often be adequately described as a function of time within a certain range. If the location of the ground zero, and the size of explosive are known, the corresponding blast loading for an existing structure may be found. However, it will never be possible to have exact data for specifying the expected ground zero and bomb size. Thus the research proposed herein is an attempt to determine the numerical response of a seismically designed idealized SDOF solitary structure to blast loading. The aspect of mitigation strategies from blast threats, easiest and least expensive ways to achieve some desired level of protection is to keep the explosion as far away as possible from structures by maximizing the stand-off distances. This measure can be achieved by providing walls or fences or bollards, fences on the perimeter of structures. But urban setting often come as hurdle due to space constraint. Thus if sufficient stand-off distances are not available for such particular structure, protective hardening of the structural components may be required and retrofitting may be needed. With limited scope of this paper, system with symmetric configuration has been proposed here to give an idea for the protection, like the distance and height of fencing to be constructed to protect the structure and minimize the losses. The non-linear equation of motion associated with the structural system proposes to analyze in time domain using Newmark's β-γ scheme with the consideration of average acceleration over each incremental time step. Modified Newton-Raphson technique is used to perform iteration in each time increment. Effect of blast is taken as time varying external force, which is determined from the product of area under the influence and blast pressure. A developed simplified uni-axial hysteresis model with incorporation of post yield stiffness and pinching stiffness has been considered for realistic behavior of structural elements. Thus finally response of blast loading in the form maximum normalized displacement to seismic response are presented with feasible range of variation of charge weight and stand-off distance are presented in the paper. We emphasis on the large public gathering structure such as large auditoriums, opera house, theaters, etc. Such structures are generally low rise structures with not more than 3-4 storied tall in general and while in case the most important aspect of such structures are that not to be designed for any blast loading in future. Instead, designer go with conventional seismic design in general.

6. REFERENCE STRUCTURE

The idealized systems which have been considered here, a rigid deck slab supported by three lateral load-resisting elements in each of the two principal orthogonal directions Fig. 4 show in plain view and is referred to as four-element systems. This lateral load-resisting structural elements represent frames or walls having strength and stiffness in their planes only. In most low-rise buildings, lateral load-resisting elements are generally designed uniformly distributed over the plan. The lateral stiffness is distributed equally between the two idealized lateral load-resisting elements located near the edge along each of the principal

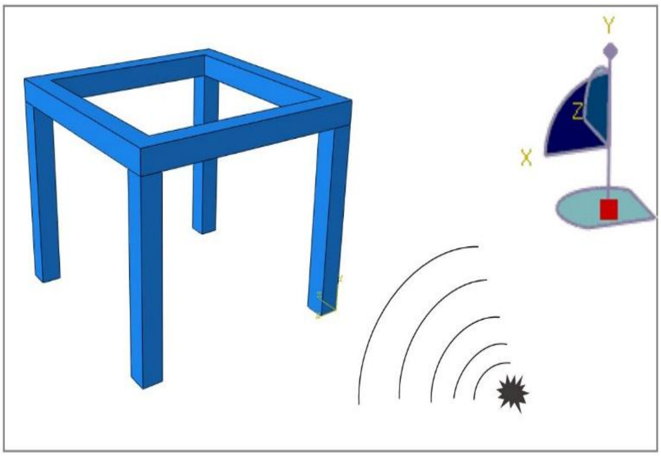


Figure-4: Reference idealized structure.

orthogonal directions, so that each of these edge elements have lateral stiffness amounting to k in flexible element and $2k$ stiff element respectively. A blast in air generates a pressure bulb, which grows in size at supersonic velocity, resulting blast wave releases a huge amount of energy over a small time duration. For stiff systems, negative phase may not be significant relative to the positive one. It is observed that blast-induced pressure wave decays exponentially, then the variation of the side-on overpressure can have expressed as:

$$p_s = p_{so}\,(1 - t/t_0)\, e^{-\alpha t/t_0} \quad (1)$$

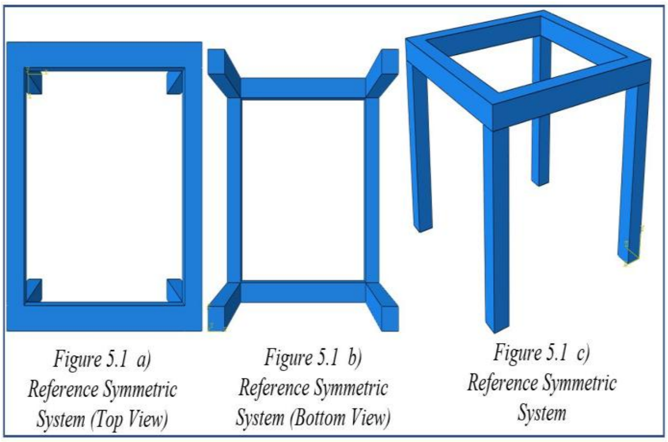
Where, p_{so} is the peak side-on overpressure, t_o is the time for positive phase of side-on overpressure in millisecond and α is the decay parameter defined from shape parameter and the maximum magnitude of the negative phase pressure. This above equation to illustrate the blast wave profile was originally proposed by Friedlander. Parameter involving in above equation for mathematical modelling of blast load may be expressed in terms of charge weight and stand-off distance. Thus the primary step in blast-resistant design is to know the above mentioned blast wave parameters and various empirical and practical results suggests that at sea level all blast wave parameters can be conveniently calculated as a function of scaled distance Z in $m/kg^{1/3}$ as:

$$Z = R/w^{1/3} \quad (2)$$

Where, R stands for stand-off distance which is the actual distance from the blast source to point under consideration where blast wave hits and W is the TNT equivalent mass of explosive measured in tonnes.

7. METHODOLOGY

Conversion of explosions into equivalent blast loads with time history has been well established in various works. For this research purpose, the intention is to apply a blast load that can definitely inflict damage to the frame. Accordingly, parametric study proved that an arbitrary 1 ton of TNT explosives at a distance from 15 m is reasonable. The explosive material is assumed to be at ground surface. To model complex pressure-time history resulting from the applied explosion, the idealization depicted in figure 4 was made. It simulates the chain of high magnitude shock fronts that get magnifies by reflected waves. Generally, community like structures have their load resisting elements in boundary area only. Here in this research a similar one story frame is considered as shown in Fig. 5.1. The system is consisted of a rigid deck supported by two lateral load-resisting element in each two orthogonal directions thus it has four members with similar material properties. The non-linear equation of motion associated with the referred structural proposal to analyze in time domain using Newmark's β-γ scheme with the consideration of average acceleration over each incremental time step.



Modified Newton-Raphson technique is proposed to use to perform iteration in each time increment. Effect of blast is taken as time varying external force, which can be determined from the product of area under the influence and blast pressure. The non-linear equation of motions is solved in the time domain in ABAQUS using Newmark's β-γ scheme (Explicit). Newmark's parameters $\beta = 0.25$ and $\gamma = 0.5$ were taken for conditional stability. ABAQUS program is used to perform iteration in each step time with modified Newton-Raphson technique using the pressure vs time data obtained from RC blast program. The Abaqus/Standard solid element library includes first-order (linear) interpolation elements and second-order (quadratic) interpolation elements in one, two, or three dimensions. Triangles and quadrilaterals are available in two dimensions; and tetrahedral, triangular prisms and hexahedral ("bricks") are provided in three dimensions. Modified second-order triangular and tetrahedral elements are also provided.

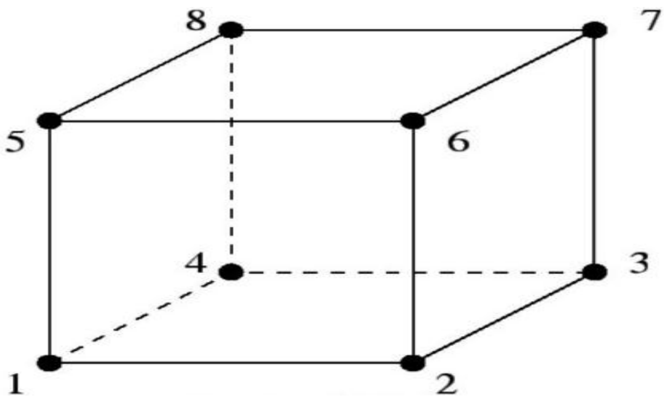


Figure-6: Hexahedral brick elements.

The Abaqus/Explicit solid element library includes first-order (linear) interpolation elements and modified second-order interpolation elements in two or three dimensions. Triangular and quadrilateral first-order elements are available in two dimensions; and tetrahedral, triangular prism, and hexahedral ("brick") first-order elements are available in three dimensions. The modified second-order elements are limited to triangles and tetrahedral. The acoustic elements in Abaqus/Explicit are limited to first-order (linear) interpolations. For this research purpose a 3-D solid beam model has been assumed with geometrically symmetrical dimensions like the cross section was taken as 300 mm × 300 mm and element length and height as 2800 m as shown in Fig. 5.1c). The material properties such as concrete grade was taken as M25 with material density 2.4, E - 9 kN/mm³, Young's modulus of 20,000 MPa and Poisson's ratio of concrete as 0.14. The section has been extruded in 3D form, rotated and translated to required one story frame with four columns and four beam. The time dependent pressure data obtained from RC Blast has been arranged in tabular form of amplitudes having selected suitable intervals. Then a blast step is defined as dynamic Explicit function in non-linear equation of motion with total time of positive phase pressure only. Because even total duration of the positive phase being a few milliseconds (two to five times less than negative phase), the maximum negative overpressure is much smaller than the peak positive overpressure, its limiting value being one atmosphere. Then load in the form of pressure is assigned in z-direction along with defining the boundary condition as shown in Fig. 7. After which the model is meshed with approximate global size of 50 units of finite element in hexahedral form shown in Fig. 8.

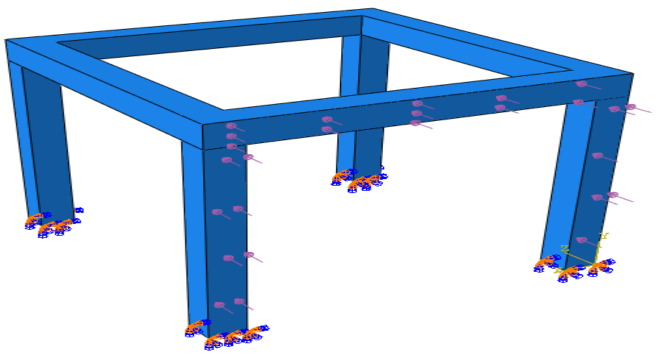


Figure-7: Loads in z-direction and boundary condition.

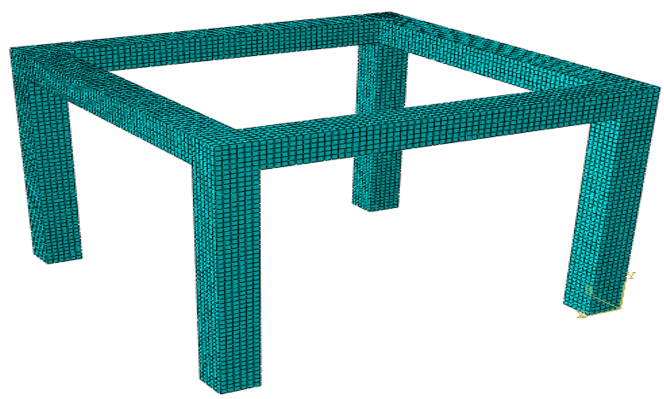


Figure-8: Meshed Frame.

In the post processing to obtain the displacement vs time graph, XY data has been created using tools menu in ODB field output and a node (Node No. 40) is chosen and data has been extracted Then the model is meshed and analyzed for result. This gives the nodal displacement that was taken as the output.

8. RESULT ANALYSIS AND DISCUSSION

Using RC Blast computer program, the pressure vs time curve is obtaining by defining parameter such as charge weight and standoff distance as per standard code [1]. In this, charge weight (TNT equivalent) constant at 0.25 ton, 0.50 ton, 0.75 ton, 1.00 ton respectively and varying the stand-off distance starting from 15 m and proceeding to a value where negative phase vanishes is plotted. The charge weigth of 1 ton has been taken out to analysis for getting higher displacement and finding out more damage. Figs. 9 to 16 have will help to understand the behavior of the idealized SDOF asymmetric

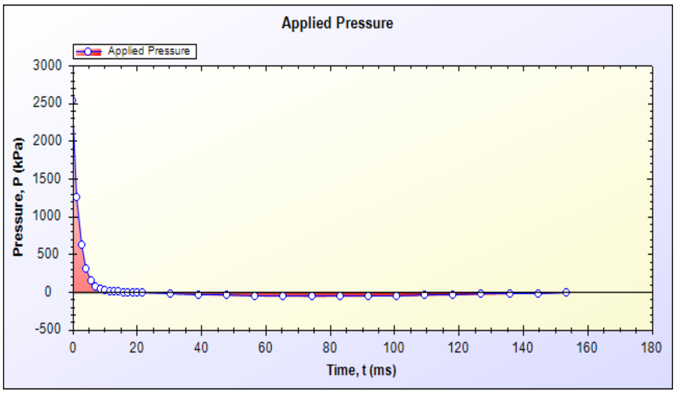


Figure-9: Response for stand-off distance 15 m at charged weight 1 ton.

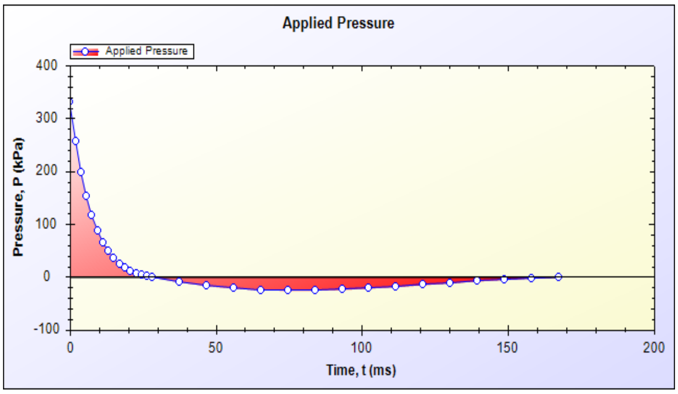


Figure-10: Response for stand-off distance 30 m at charged weight 1 ton.

structure that has been taken here. For the displacement from the iteration data obtained in ABAQUS, a node in the XY plane with node no. 40 has been selected for reference of nodal displacement.

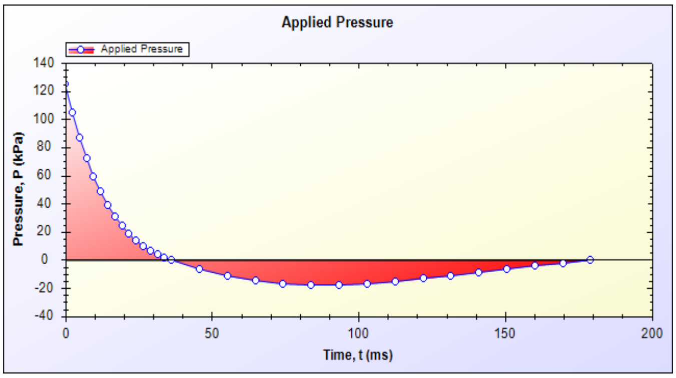


Figure-11: Response for stand-off distance 45 m at charged weight 1 ton.

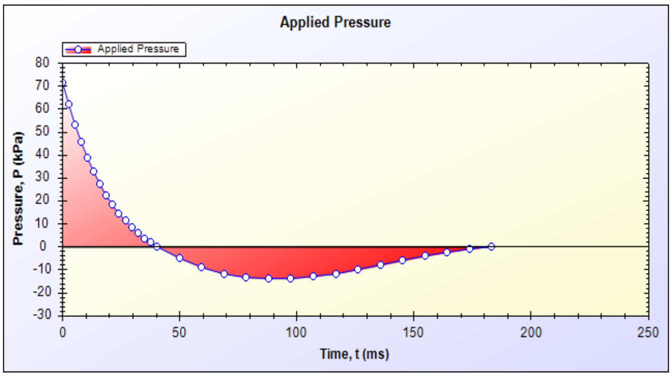


Figure-12: Response for stand-off distance 60 m at charged weight 1 ton.

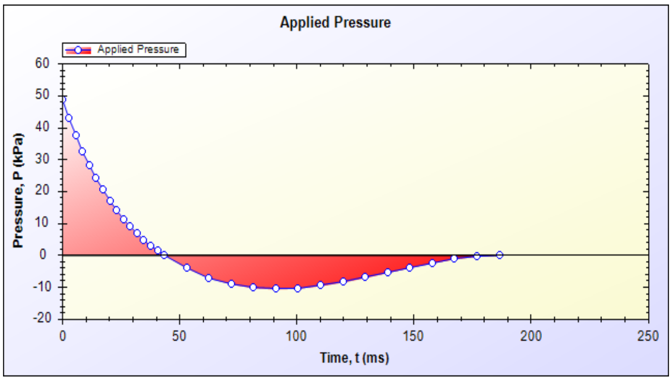


Figure-13: Response for stand-off distance 75 m at charged weight 1 ton.

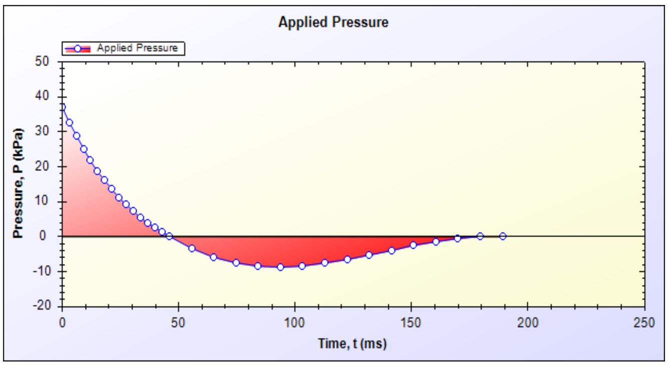


Figure-14: Response for stand-off distance 90 m at charged weight 1 ton.

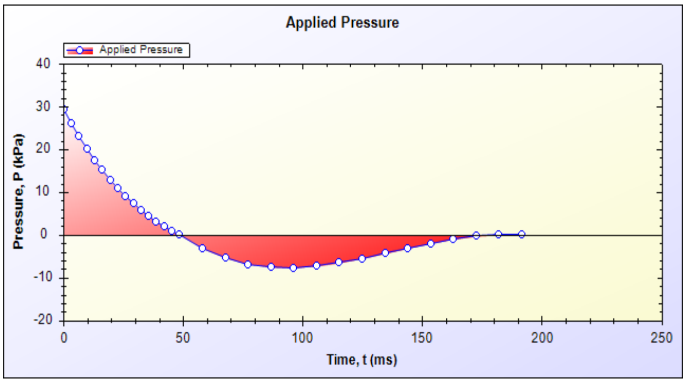


Figure-15: Response for stand-off distance 105 m at charged weight 1 ton.

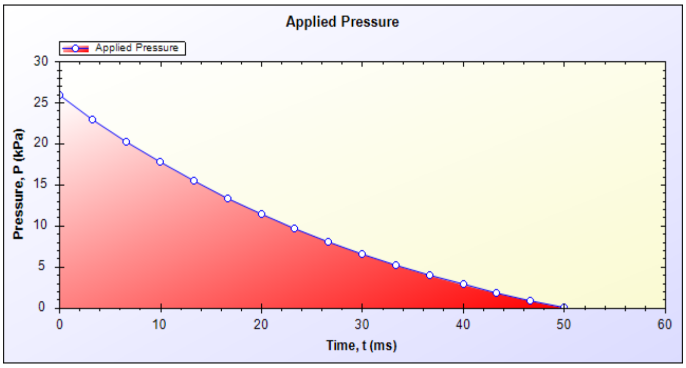


Figure-16: Response for stand-off distance 115 m at charged weight 1 ton.

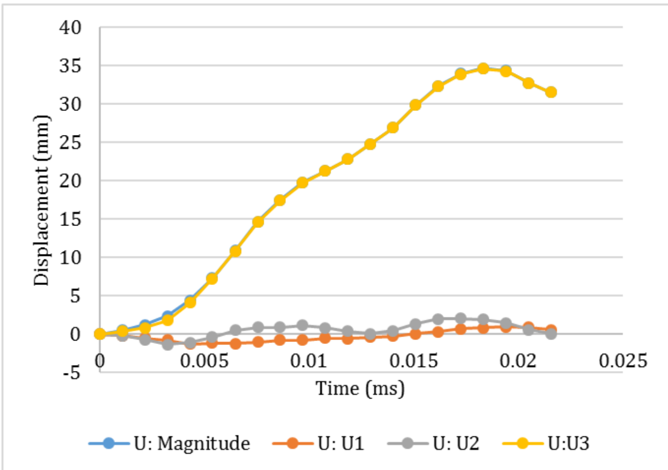


Figure-17: Maximum displacement response for stand-off distance 15 m at charge weight 1 ton.

From maximum pressure due to different time interval figures obtained for R/C structural system due to blast loading as shown in Figs. 9-16 is found that the structure may be collapsed if the charge weight of 1 ton is kept at a distance less than 15m. Distance 15m to next standoff distance of 30 m, the peak pressure drastically drops from 2528.4 KPa to 330 KPa (over 7 times), then after the pressure reduces around 50% at subsequent intervals further as the charge weight moves away from the structure.

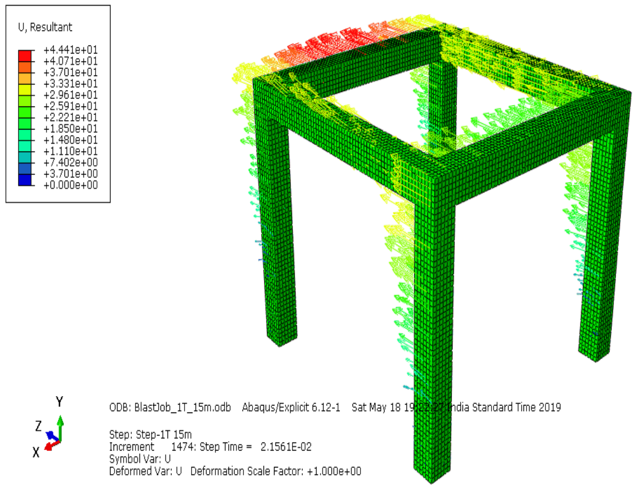


Figure-18: Deformed Shape for stand-off distance 15 m at charge weight 1 ton.

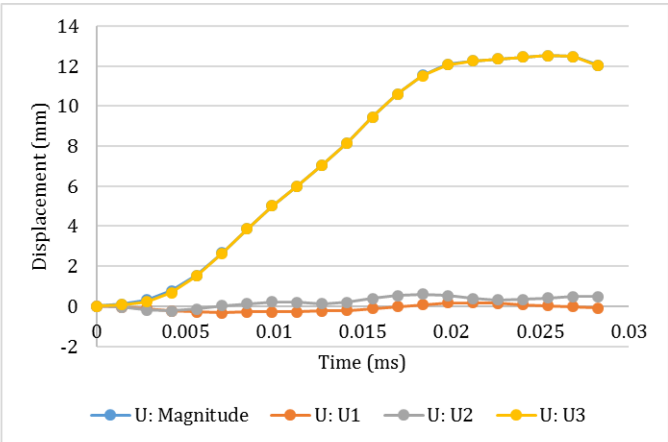


Figure-19: Maximum displacement response for stand-off distance 30 m at charge weight 1 ton.

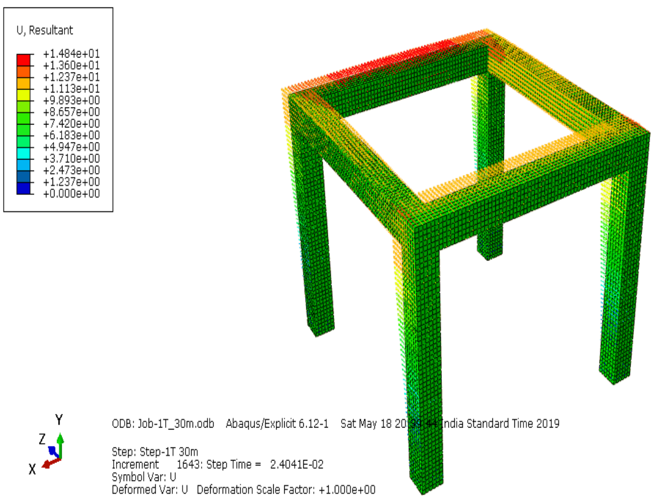


Figure-20: Deformed Shape for stand-off distance 30 m at charge weight 1 ton.

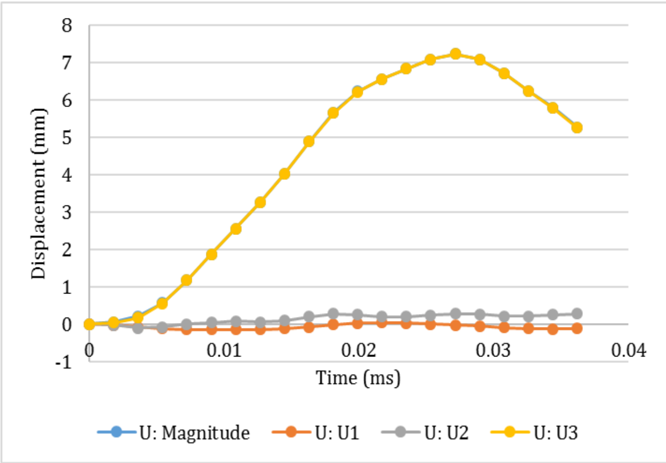


Figure-21: Maximum displacement response for stand-off distance 45 m at charge weight 1 ton.

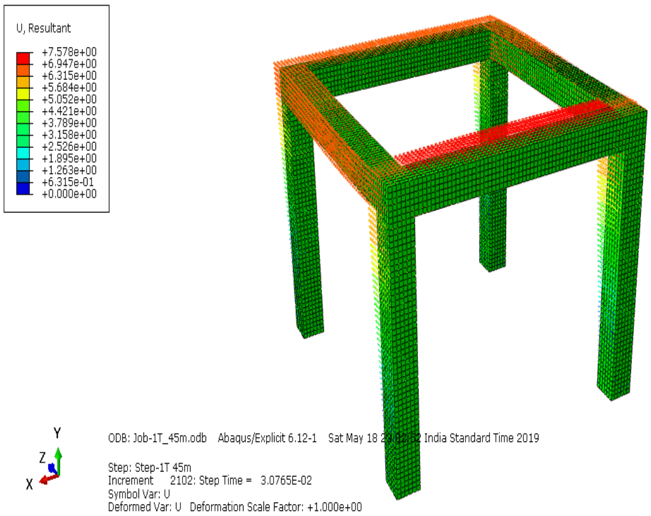


Figure-22: Deformed Shape for stand-off distance 45 m at charge weight 1 ton.

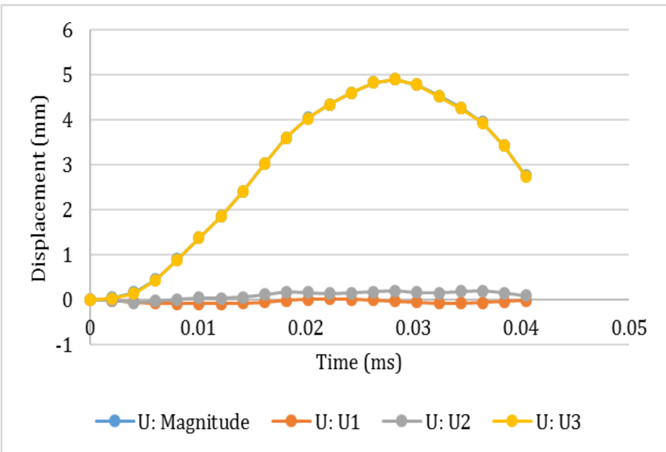


Figure-23: Maximum displacement response for stand-off distance 60 m at charge weight 1 ton.

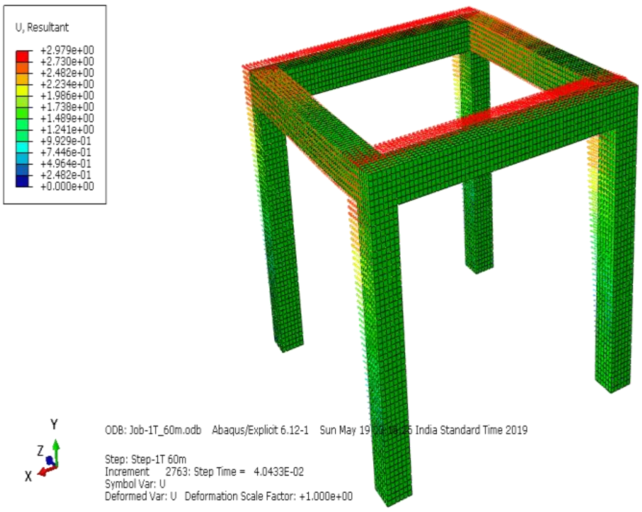


Figure-24: Deformed Shape for stand-off distance 60 m at charge weight 1 ton.

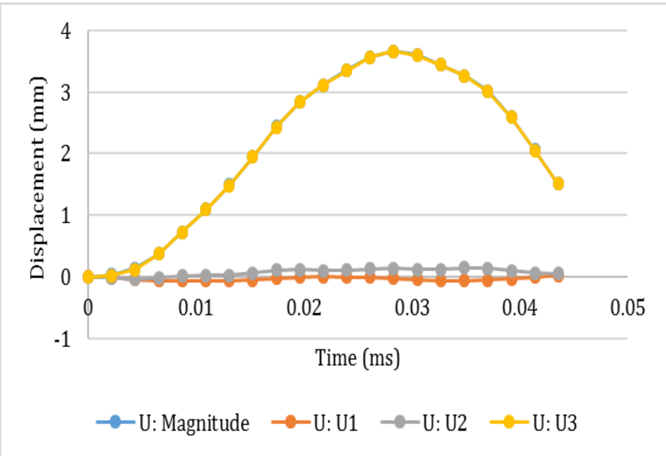


Figure-25: Maximum displacement response for stand-off distance 75 m at charge weight 1 ton.

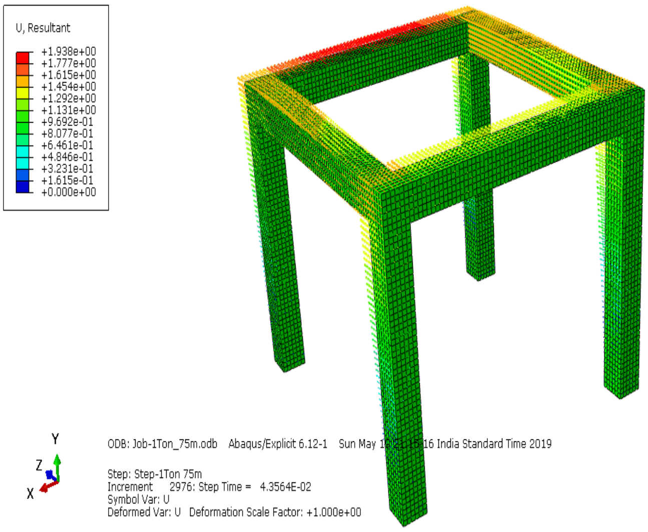


Figure-26: Deformed Shape for stand-off distance 75 m at charge weight 1 ton.

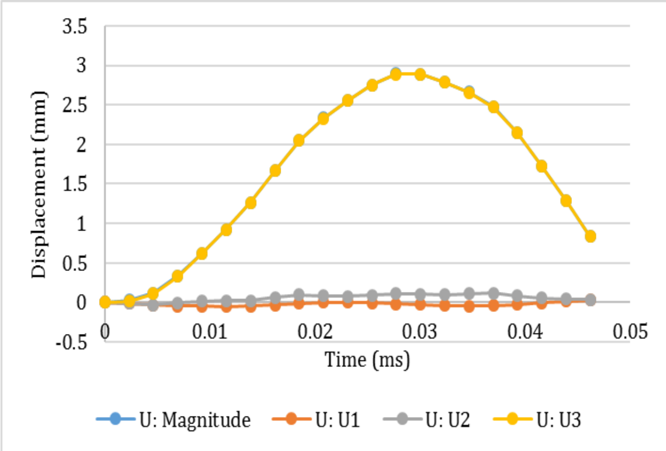


Figure-27: Maximum displacement response for stand-off distance 90 m at charge weight 1 ton.

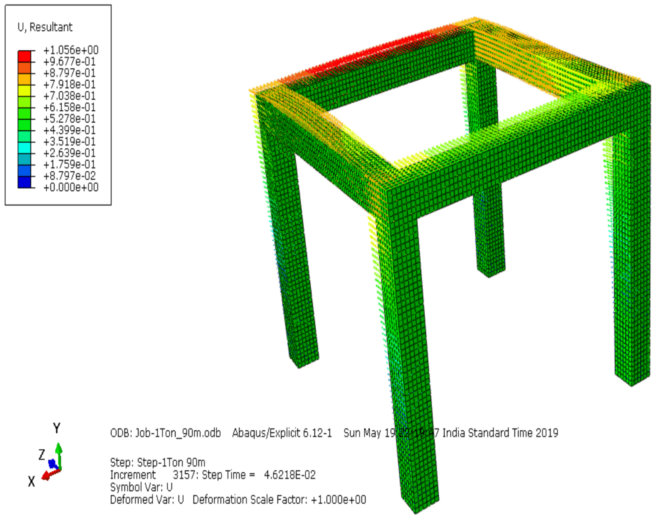


Figure-28: Deformed Shape for stand-off distance 90 m at charge weight 1 ton.

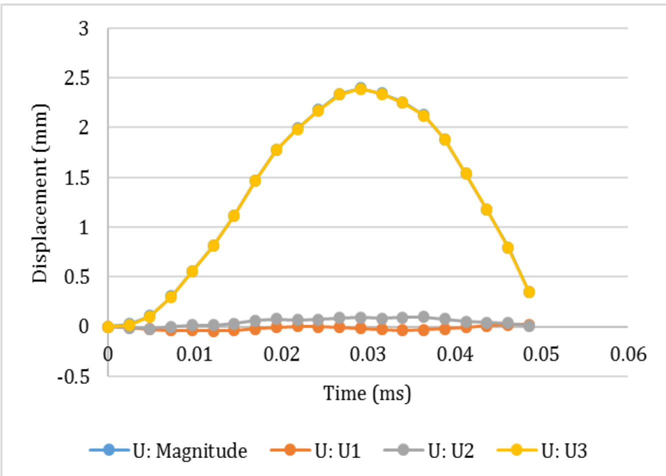


Figure-29: Maximum displacement response for stand-off distance 105 m at charge weight 1 ton.

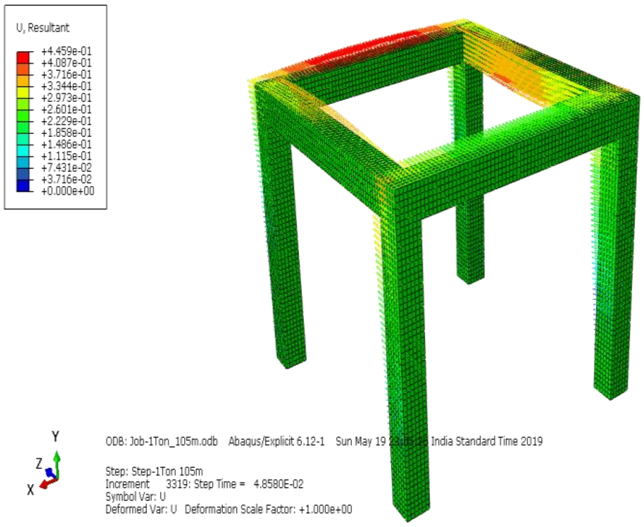


Figure-30: Deformed Shape for stand-off distance 105 m at charge weight 1 ton.

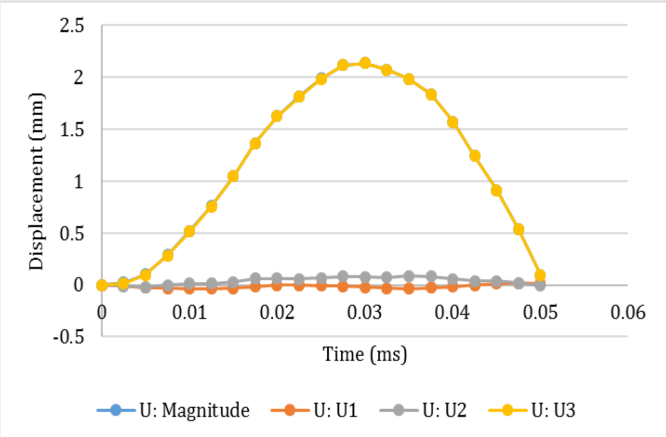


Figure-31: Maximum displacement response for stand-off distance 115 m at charge weight 1 ton.

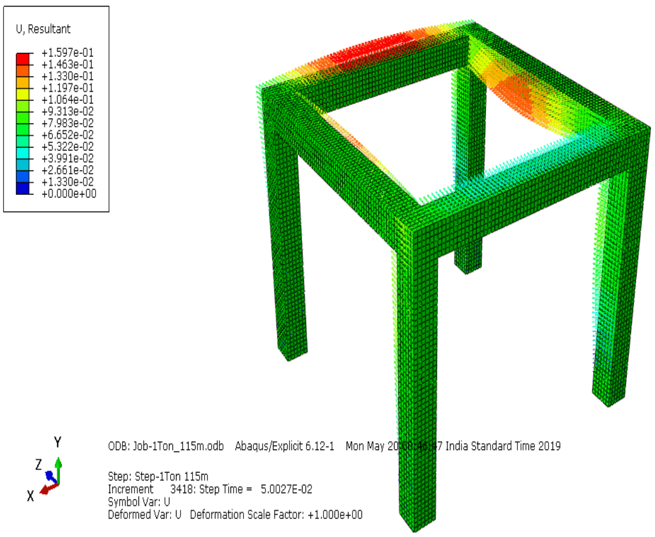


Figure-32: Deformed Shape for stand-off distance 115 m at charge weight 1 ton.

In addition, around 90 m to 105 m the pressure drops are almost similar was found that the negative phase of the pressure disappears and also the duration of positive phase doubles from the initial stand-off distance to this distance. After observing the output data obtained from a particular node (node no. 40) of the structure shown from Figs. 17-32 onwards, it is noted that at a closer distance of 15 m there is excessive displacement of 34.6 mm at a very small time of 0.0183 milliseconds after the blast occurred. As moving the charge weight further away from the building at an interval of 15m, the displacement drastically reduces to 10 times at a distance of 75 m i.e. 3.66 mm which is accepted as it won't cause any significant damage such as cracks in structure. Hence, this distance may be assumed to be safe for the structure. Also at a distance of 45 m the displacement is 7.22 mm, hence this distance may also be taken safety distance considering any mitigation measures suggested.

Table-1: Near-Fault (NF) ground motions used.

Sl no.	**Event (Year)**	**Station**	**Record ID**	**Moment magnitude (M_w)**	**PGA (m/s^2)**	
					X - Component	**Y - Component**
1.	Landers, 1992	Morongo Valley Fire Station	RSN881	7.3	2.19	1.61
2.	Tottori Japan, 2000	OKY004	RSN3907	6.7	8.08	5.28
3.	Iwate_ Japan, 2008	MYG005	RSN5664	6.9	5.25	4.37
4.	Imperial valley-1979	El centro Array#4	RSN179	6.5	4.75	3.63
5.	Kocali, Turkey,1999	Duzce	RSN1158	7.5	3.06	3.57
6.	Loma Prieta_ 1989	Los Gatos Lexington Dam	RSN3548	6.9	4.34	4.04
7.	Denali, Alaska _2002	TAPS Pump Station #10	RSN2114	7.9	3.26	2.92

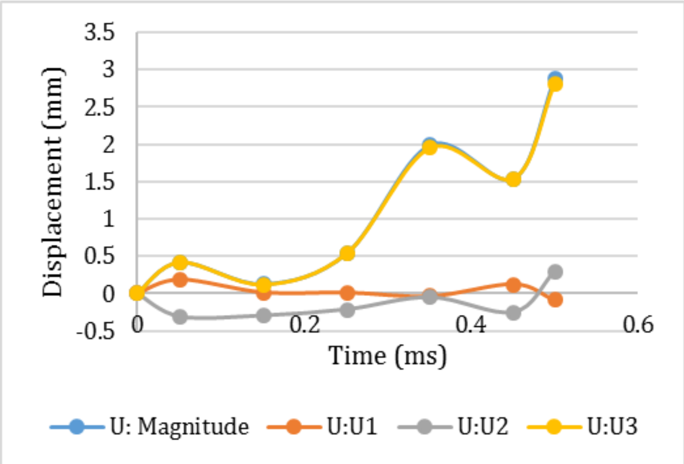


Figure-33: Maximum normalized displacement response due to NF ground motions.

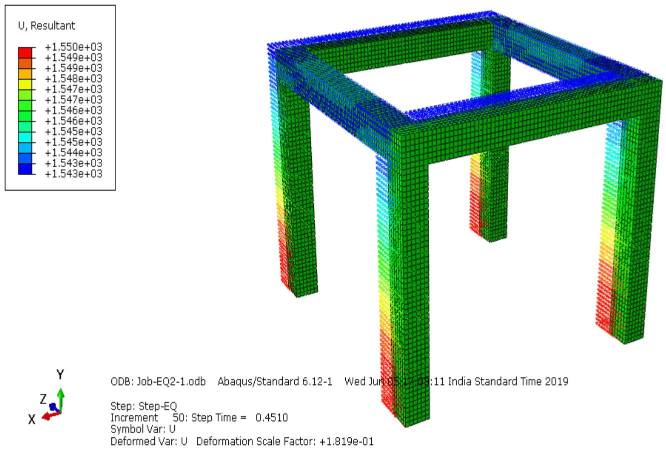


Figure-34: Deformed shape response due to NF ground motions.

The seismic analysis owing to seven scaled near-fault synthetic ground motions show in Table 1 are selected from PEER center in terms of geophysical parameters [26-29]. For simplicity, the earthquake duration of 0 to 0.5 sec has been considered and the maximum normalized displacement response for structural elements is obtained as shown in Figs. 33 and 34. In this case ductility reduction factor [26-29] chosen as 1. This NF database, the structure distorted with the range of 1.2-2.8 mm which may leave damage to the structure due to its longer duration.

9. CONCLUSIONS

This study analysis is to understand the response between blast load and seismic excitation in an idealized SDOF one story R/C frame structure. This work also gives an overall response of the structure, other than the evolution of localized damage. The following brief conclusion is emerged.

1. The blast pressure drastically drops from 2528.41 KPa at 15 m to 12.12 KPa at 45 m from the structure (almost 20 times) i.e. to a nominal level and for the same distance the displacement reduces from 34.6 mm to 7.22 mm (almost 5 times) is perfectly observed.
2. The earthquake displaces the building such that it may leave some damage if no prior measures hasn't been taken during designing phase of the structure. Considering the building is suited in a city area where building density is medium to high. This distance of 45 m can be assumed to be safe distance from the structure for making a high boundary wall for a standard charged weight of 1 ton, which is capable by itself to reduce or absorb the intensity of blast pressure by virtue of reinforcement and its thickness.
3. The entrance should not be directly exposed gate, instead a barrier should be providing so that it may act as a wall in case blast occurs in front of the entrance. In addition, it will be advisable to use bollard or planter outside the wall fence to further minimize the damage. Also, altering the design of external columns and walls including cladding material over glass panes so it does not shatter during an event of earthquake or blast, use of shear wall, etc. may also significantly decrease the risk to the structure and the inhabitants. While designing building of public gathering like malls, offices, schools or colleges a safe place or structure should be located to act as safe heaven or muster station to hide out safely during emergency situations like earthquake.

With the limited scope of this research done herein only in the front face of this generalized structure. Hence, data of this study may be reviewed through better model of blast accounting for the effects on asymmetric structure on side walls (including rear wall) and roof. Also, work can be done by considering the angle of air burst incident to the structure although which is assumed as perpendicular in general. Also study emphasing on the behaviour of various types of material used for construction of such structure. In this research the structure is idolized as SDOF single story simple structure, resembling a general auditorium like structure. Hence, work can be done by taking more complex structure with multiple degrees of freedom and multiple story.

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