Non-Linear Analysis of a G+10 Reinforced Concrete Framed Structure Subjected to Blast Load

Rathlavath Raghavendra and Pachipala Sravani

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Rathlavath Raghavendra[a], Sravani Pachipala[b]

[a] *M-Tech Student, Department of Civil Engineering,*
[b] *Assistant Professor, Department of Civil Engineering,*
Vardhaman College of Engineering, Shamshabad, Hyderabad - 501218, India,

a) *E-mail: rathlavathrps.2@gmail.com*
b) *E-mail: sravanipachipala@vardhaman.org*

Abstract. Impact of disasters provides huge property loss, life loss and climatic changes. Consideration of disasters in design is more important to avoid losses. Disasters are mainly of two types i.e. natural and artificial disasters. The main cause for artificial disasters is terrorists attack, domestical gas blast and any industrial leakages turned to blast. Generally, blast loads are not considered in the design of structures because these are man-made disasters. A structure should be designed in such manner that it has to endure the blast loads also. Blast loads can be designed as dynamic loads. Effect of blast load depends on the point of occurrence of blast and also length b/w the structure or structural element from the blast and wave propagation due to blast. The current research mainly focuses on blast studies and also to study the behaviour of G+10 structure with and without in-fills when it is exposed to blast loads. Damage assessment of structural member can be assessed by analyzing the structure in ETABS software. The response of the structure is studied in terms of displacements, storey drifts and stress contours. Design a structure by adopting the best technique i.e. shear wall to resist blast load also to make the structure sustainable.

Keywords: Blast load, Displacements, Storey drifts, Shear wall, In-filled frame

1. Introduction:

The terrorist attacks and domestical explosions have risen significantly in recent decades. These are the manmade disasters. Huge quantity of energy is unexpectedly released into the atmosphere as explosion happens as a result the material undergoes physical and chemical changes. This happens when stored potential energy is suddenly converted into mechanical work, resulting in a blast wave and a loud noise. Nuclear explosions originate from the release of energy-building protons and neutrons within the atomic nuclei, whereas conventional explosives like trinitrotoluene (Trinitrotoluene) rely on the rearranging of their atoms for energy. Blast explosives are complex issues which occur in short time and its high intensity causes variations in the structural response.Importance is given to predict the destruction caused by the sudden manmade disasters. Prediction is not only enough to minimize the intensity of damage. Proper mitigation methodologies have to be adopted to diminish the damage.

Blast or detonation is a pressure emitted by speedy action of force or energy. There are numerous forms of High blasts or explosives accessible and as all explosive or detonate have their own Explosion or detonation properties or characteristics, the characteristics of each blast wave will be different. Blasts caused by advanced explosives similar Trinitrotoluene are called detonations or explosions where as they caused by low level explosives are known as deflagration Trinitrotoluene is used as the fixed or standard benchmark, all blasts can be express in terms of an equivalent weight charge mass of Trinitrotoluene. The most regular method of equalization is founded on the ratio of a detonates or blast's specific energy to that of Trinitrotoluene When a Trinitrotoluene explodes, a pressure wave is generated by the explosion that applies a force or load on the surrounded buildings or structures. The blast wave starts transfer from the detention point of explosion approximately in spherical wave and upon contact any surface or land or ground, the wave is reflected and modified In the design procedure it is essential to find the expected danger and the severity of the danger. Most significantly human safety should be given during an exact event, the action of the blast load depends on the fundamental interaction of the load with the surface of the structure or building, atmospherical pressure at the time of the situation, weather conditions at the time of blast loading and some other element which are usually ignored for a easy analysis. The design of these structures when all these effects are considered will lead to

uneconomical economy. The structural response to blast load can be found, either more precisely by a calculation or roughly based on empiric formulas.
Generally, explosion occurs in two ways i.e. natural and man-made. Man-made disasters are classified into three types i.e. confined explosion, unconfined explosion and explosion caused by unexpected chemical reaction or gases.
The effect of blast are in 3 forms fire,fragments and pressure waves the structure is very much strong in case of fire and fragments but in case of pressure wave the structure has more chances of collapse which may turn in huge human loss and property loss.

2. Blast study

Blast has majorly 3 types of blasts confined explosion, unconfined explosion and Explosion caused by unexpected chemical reaction or gases all most all types of major blast comes under theses categories only

2.1 Confined explosion:

Explosion takes place inside the building or structure is called as confined explosion. In the confined explosion, the maximum pressures related with the starting wave fronts are highly severe.

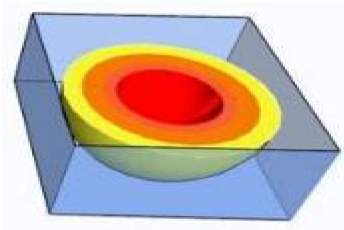


FIGURE.1 Confined explosion

2.2 Unconfined explosion:

Explosion takes place in open areas is called as unconfined explosion. In this type of explosion, the wave extended from the source of blast to the structure or building without any wave increase.

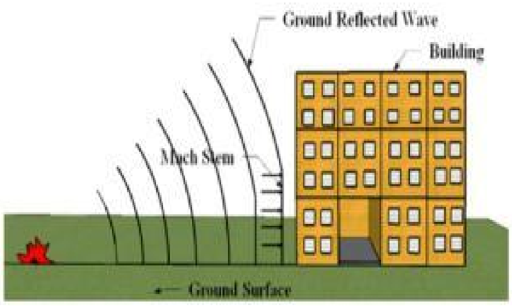


FIGURE.2 Unconfined explosion

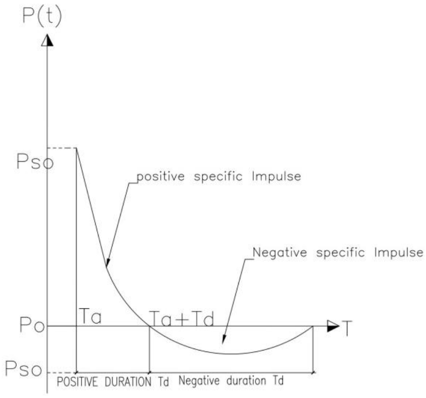
2.3 Explosion caused by unexpected chemical reaction or gases

These are also called as domestic explosions which causes due to leaks from gas powered kitchen appliances used for heating.

FIGURE.3 Domestic explosion

2.4 Characteristics of blast wave:

An perfect pressure level-time history shows the crucial elements of pressure wave or blast load is portrayed in beneath figure



FIGUREure 4: Blast wave pressure – Time history

The various parameters of this idealized curve are: P_o = Ambient pressure P_{so} = Peak positive side-on over pressure P_{so-} = Peak negative side-on over pressure $P_{s(t)}$ = Time varying positive over pressure $P_{s(t)}$ = Time varying negative over pressure I_s = Positive phase specific impulse, the integration of the positive phase pressure-time history I_{s-} = Negative phase specific impulse, the integration of the negative phase pressure-time history t_a = Time of arrival t_d = Positive phase duration t_{d-} = Negative phase duration

3. Description of the Model

3.1 *Structure parameters*

The structure is a G+10 reinforced concrete framed structure. It consists of 3 bays in X-direction and 3 bays in Y-direction. Bay length in X & Y- direction is 4m. Height of storey is 3m. Total dimensions of the structure are 12m length, 12m breadth and 33m height. Size of columns is 500mmx500mm, size of beams is 400mmx400mm, thickness of slab is 150mm and thickness of walls is 250mm is adopted to design the structure. M30 grade concrete and Fe415 steel is used in this structure. Shear wall is a wall which is designed to resist the lateral loads.

3.2 Blast Parameters

Blast load is designed for unconfined explosive of capacity 50Kg Trinitrotoluene (Trinitrotoluene). The point of explosion is called as detonation point. The distance from detonation point to the structure is 30m. The distance from detonation point to the bottom of the structure is 42.42m and the distance between detonation point and top of the structure is 42.42m.

3.3 Load calculations

Calculation of load when structure subjected to unconfined blast explosive is done according to IS 4991-1968.

Table 2.1 – Blast load calculations

S.No.	Blast parameter	Value
1.	Scaled distance	81.432m
2.	Ambient atmospheric pressure (p_a)	1.00 kg/cm^3
3.	Peak positive side-on over pressure (p_{so})	0.25 kg/cm^2
4.	Mach number (M)	1.1
5.	Positive phase duration (t_o)	41.58 milliseconds
6.	Duration of the equivalent triangular pulse (t_d)	31.92 milliseconds
7.	Peak dynamic pressure (q_O)	0.022kg/cm^2
8.	Reflected overpressure (p_{ro})	0.55kg/cm^2
9.	Velocity of sound in air (a)	344m/s
10.	Shock front velocity (U)	0.378m/ms
11.	S	6
12.	Clearance time (t_c)	47.508 milliseconds
13.	Transit time (T_t)	39.59 milliseconds
14.	T_r	63.345 milliseconds
15.	Pressure on face	0.549 kg/cm^2
16.	Pressure on roof and side walls	0.248kg/cm^2

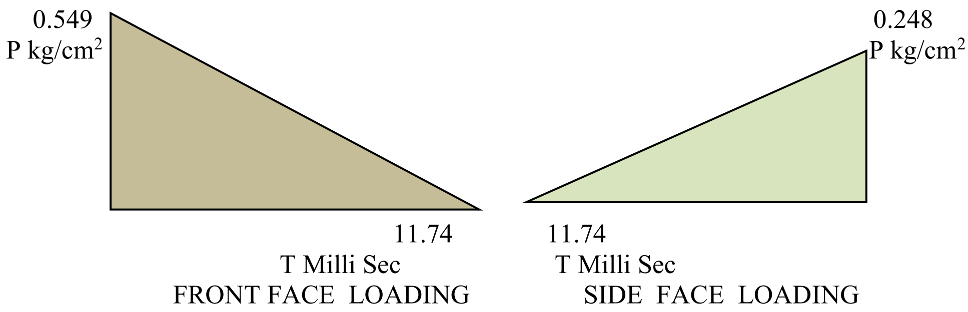


Fig. 5. Load calculations

4. Effect of blast load on G+10 reinforced concrete frames

G+10 structure with infills and without infills is designed in Etabs. Blast load is applied as pressure in the form of uniformly varying load on beams and columns. Also dead and live loads are applied according to IS 875 and its parts.

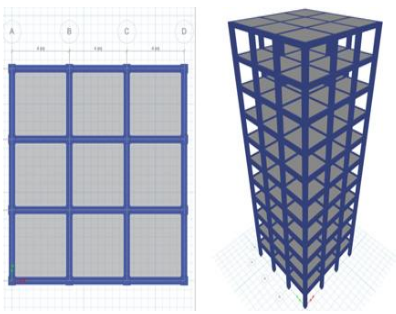


Fig. 6 Model of G+10 frame without infills

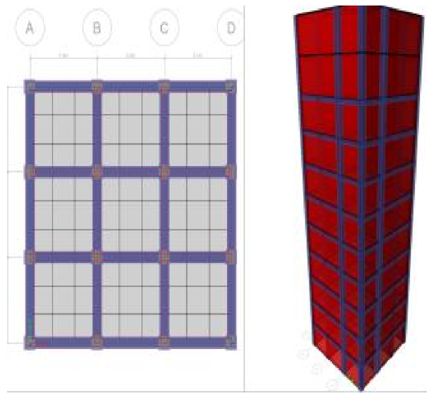


Fig.7 Model of G+10 frame with infills

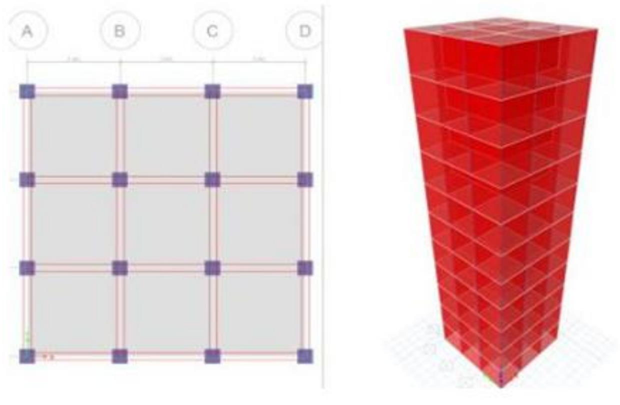
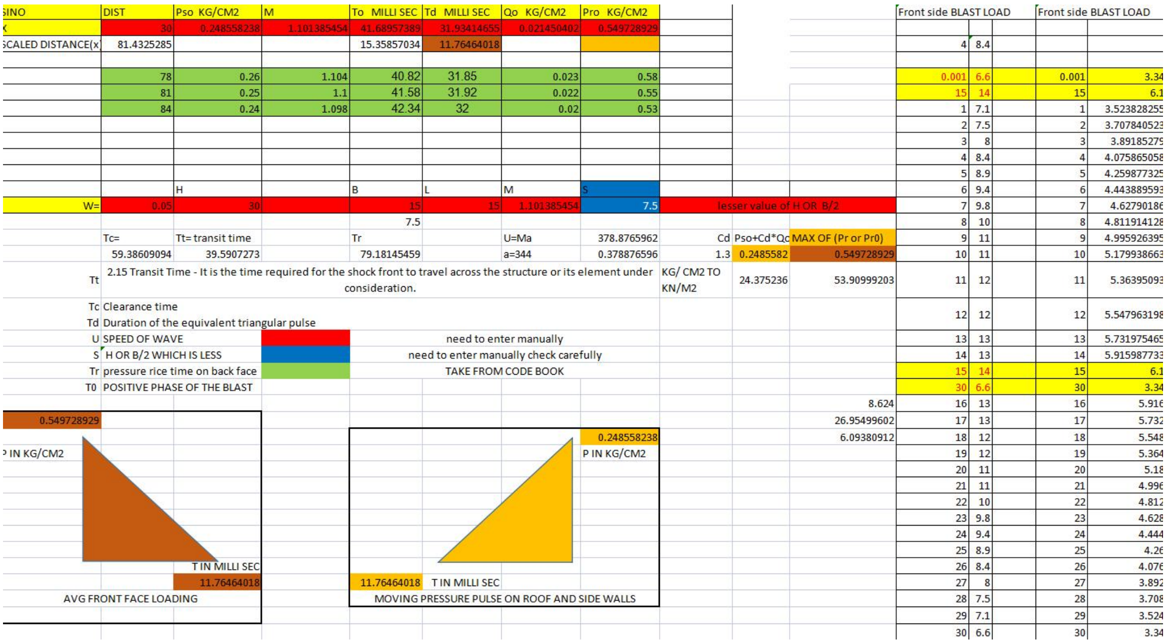


Fig.8 Model of G+10 frame with shear wall

4.1 Application of loads on the structure

4.1.1 load calculation



SINO	DIST	Pso KG/CM2	M	To MILLI SEC	Td MILLI SEC	Qo KG/CM2	Pro KG/CM2
X	30	0.248558238	1.101385454	41.68957389	31.93414655	0.021450402	0.549728929
SCALED DISTANCE(x)	81.4325285			15.35857034	11.76464018		
	78	0.26	1.104	40.82	31.85	0.023	0.58
	81	0.25	1.1	41.58	31.92	0.022	0.55
	84	0.24	1.098	42.34	32	0.02	0.53
		H		B	L	M	S
W=	0.05	30		15	15	1.101385454	7.5
				7.5			

lesser value of H OR B/2

Tc=	Tt= transit time		Tr		U=Ma	378.8765962	Cd	Pso+Cd*Qc	MAX OF (Pr or Pr0)
59.38609094	39.5907273		79.18145459		a=344	0.378876596	1.3	0.2485582	0.549728929
						KG/ CM2 TO KN/M2		24.375236	53.90999203

Tt 2.15 Transit Time - It is the time required for the shock front to travel across the structure or its element under consideration.

Tc Clearance time

Td Duration of the equivalent triangular pulse

U SPEED OF WAVE — need to enter manually

S H OR B/2 WHICH IS LESS — need to enter manually check carefully

Tr pressure rice time on back face — TAKE FROM CODE BOOK

T0 POSITIVE PHASE OF THE BLAST

8.624

26.95499602

6.09380912

Front side BLAST LOAD		Front side BLAST LOAD	
4	8.4		
0.001	6.6	0.001	3.34
15	14	15	6.1
1	7.1	1	3.52382825
2	7.5	2	3.70784052
3	8	3	3.8918527
4	8.4	4	4.07586505
5	8.9	5	4.25987732
6	9.4	6	4.44388959
7	9.8	7	4.6279018
8	10	8	4.81191412
9	11	9	4.99592639
10	11	10	5.17993866
11	12	11	5.3639509
12	12	12	5.54796319
13	13	13	5.73197546
14	13	14	5.91598773
15	14	15	6.1
30	6.6	30	3.34
16	13	16	5.916
17	13	17	5.732
18	12	18	5.548
19	12	19	5.364
20	11	20	5.18
21	11	21	4.996
22	10	22	4.812
23	9.8	23	4.628
24	9.4	24	4.444
25	8.9	25	4.26
26	8.4	26	4.076
27	8	27	3.892
28	7.5	28	3.708
29	7.1	29	3.524
30	6.6	30	3.34

Fig. 9 Blast Load calculation as per IS 4991

4.2Application of load on bare frame:

Blast load is applied as uniformly varying load i.e, load decreases with the increase in distance. This also states that load and distance of the obstructing object or element has inverse relationship. Blast load is assumed to be happened at a height of 15m from the ground level and also 30m standoff distance from the detonation point. Mid-point of the structure i.e at 16.5m from the ground is subjected to maximum load and the standoff distance is increased to the top and bottom of the structure by 42.2m.

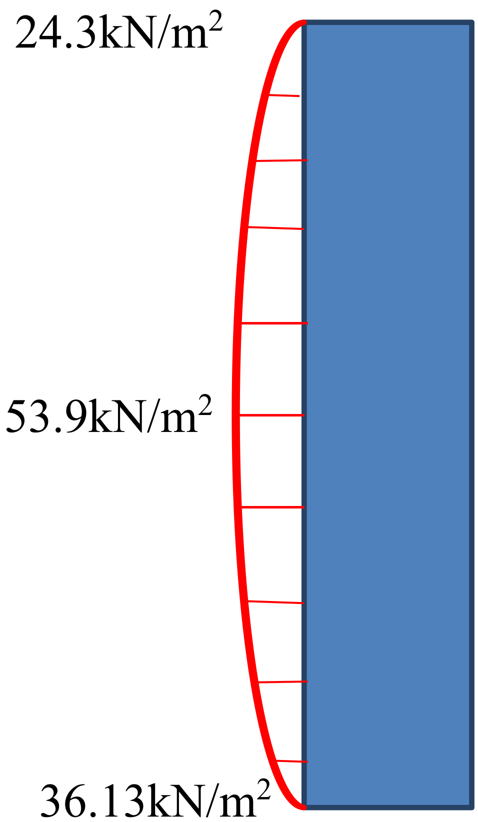


Fig. 10 Application of load on G+10 frame with shear wall

5. Results and Discussions

Storey drift is the horizontal displacement of a floor related to the floor below. Storey drift ratio is calculated by dividing storey drift with storey height. Under the application of unconfined blast load, the displacement of the storey is maximum at second storey.

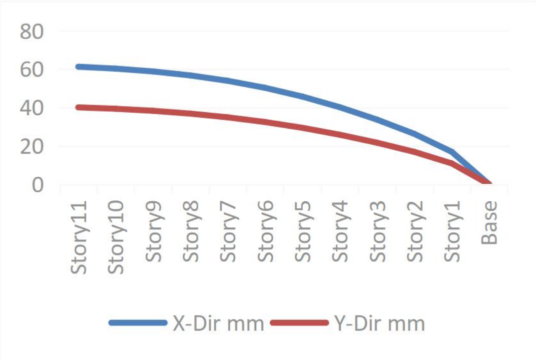


Fig. 11. Displacement profile of a frame without in-fills

Fig. 12. Displacement profile of a frame with in-fills

Blast is happening at a distance 30m from the building in open area. The frame with no in-fills is showing maximum displacement of 61.238mm & 40.064mm at eleventh storey, minimum displacement of 16.934mm & 10.879mm at first storey in X & Y directions respectively. Displacement increases with the increase in storey.

Table 4.1 – Storey displacements & drifts of a bare frame

Storey no.	Elevation (m)	Displacement(direction)		Drift(direction)	
		X-(mm)	Y-(mm)	X-(mm)	Y-(mm)
Base	0	0	0	0	0
1	3	16.934	10.879	0.005645	0.003626
2	6	26.258	16.873	0.003116	0.002007
3	9	33.686	21.65	0.00248	0.001592
4	12	40.151	25.815	0.002156	0.001389
5	15	45.69	29.417	0.001547	0.0012
6	18	50.257	32.429	0.001523	0.001005
7	21	53.899	34.875	0.001214	0.000816
8	24	56.709	36.805	0.000937	0.000644
9	27	58.787	38.272	0.000693	0.00049
10	30	60.247	39.335	0.000487	0.000355
11	33	61.238	40.064	0.000331	0.000247

But the rise in displacement is maximum at first storey of 16.934mm & 10.879mm in X and Y- directions respectively. Also storey drift is maximum at first storey of 0.005645mm & 0.003626mm in X & Y- directions respectively. The present study shows that the impact of blast load is maximum at first storey, then the effect carries along with the top stories which leads to collapse of the structure.

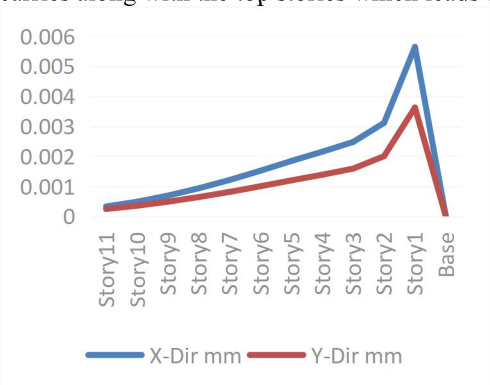


Fig. 13. Inter storey drift of a frame without infills

Fig.14. Inter storey drift profile of a frame with infills

Table 4.2 – Storey displacements & drifts of an In-filled frame

Storey no.	Elevation (m)	Displacement(direction)		Drift(direction)	
		X-(mm)	Y-(mm)	X-(mm)	Y-(mm)
Base	0	0	0	0	0
1	3	0.001	1.76E-05	1.21E-07	3.71E-08
2	6	0.003	2.11E-05	1.38E-07	1.79E-08
3	9	0.005	2.16E-05	1.56E-07	2.56E-08
4	12	0.007	2.72E-05	1.66E-07	2.69E-08
5	15	0.009	3.46E-05	1.68E-07	2.70E-08
6	18	0.012	3.48E-05	1.68E-07	2.67E-08
7	21	0.014	5.27E-05	1.65E-07	2.61E-08
8	24	0.016	8.86E-05	1.60E-07	2.51E-08
9	27	0.019	0.0001345	1.55E-07	2.41E-08
10	30	0.021	0.000195	1.50E-07	2.33E-08
11	33	0.023	0.0002291	1.46E-07	2.41E-08

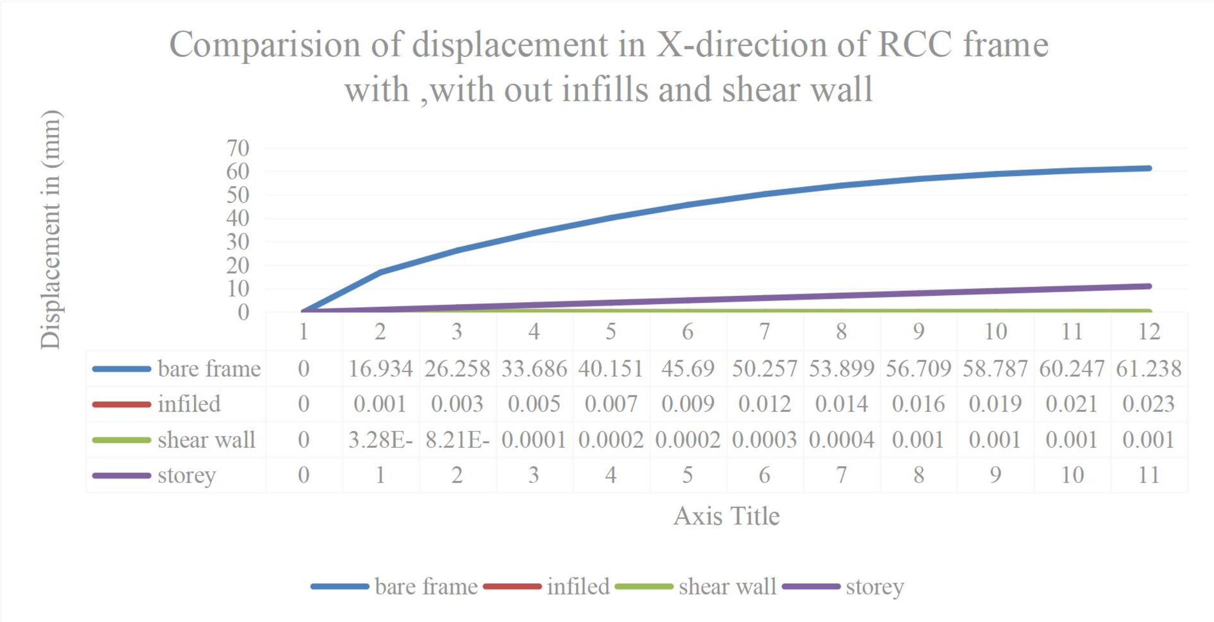
To reduce the effect of blast load in a non in-filled frame, frame is designed with in-fills. Generally in-fills are treated as non structural elements because of their load bearing characteristics. The first failure occurs in in-fills when any sudden loads are acting on the structure. Now-a-days, infills are treated as structural elements because of their stiffness characteristics.

The maximum displacement occurs at eleventh storey of 0.005mm & 0.001mm, minimum displacement occurs at first storey of 0.0003638mm & 0.0001113mm in X & Y- directions respectively. Displacement increases with the increase in storey. But the rise in displacement does not follows linear variation.

Also storey drift is maximum at fifth and sixth storey's of 1.68E-07mm in X- direction & 3.71E-08mm at first storey in Y- direction respectively there on the drift reduced as it goes to top storey.
The structure with in-fills shows that the displacement is reduced from 61.238mm to 0.005mm.

Table 4.3 – Storey displacements & drifts of a frame with shear wall

Storey no.	Elevation (m)	Displacement(direction)		Drift(direction)	
		X-(mm)	Y-(mm)	X-(mm)	Y-(mm)
Base	0	0	0	0	0
1	3	3.28E-05	6.29E-07	1.09E-08	0
2	6	8.21E-05	1.22E-06	1.64E-08	0
3	9	0.0001437	1.75E-06	2.05E-08	0
4	12	0.0002143	2.22E-06	2.36E-08	0
5	15	0.0002915	2.63E-06	2.57E-08	0
6	18	0.0003728	2.98E-06	2.71E-08	0
7	21	0.0004564	3.27E-06	2.79E-08	0
8	24	0.001	3.50E-06	2.81E-08	0
9	27	0.001	3.66E-06	2.79E-08	0
10	30	0.001	3.77E-06	2.74E-08	0
11	33	0.001	3.82E-06	2.67E-08	0



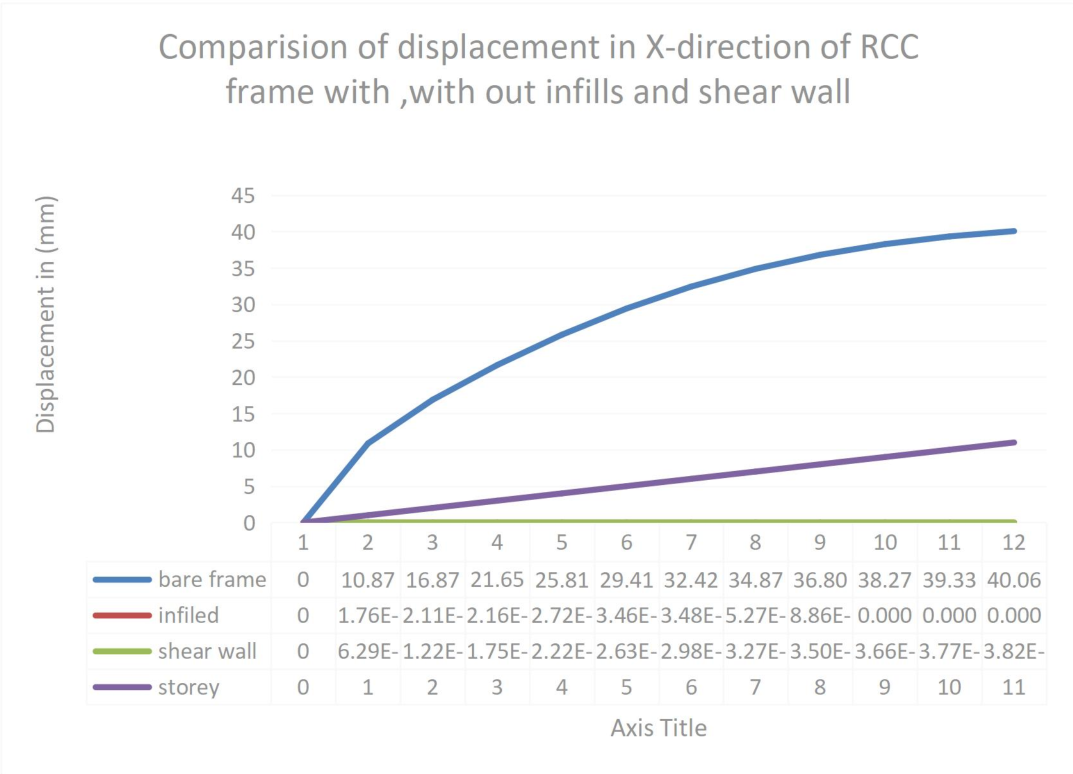


Fig.15. Displacement profile in X- direction of all models   Fig.16. Displacement profile in Y- direction of all models

One of the best technique to minimize the effect of blast load on structure is shear wall construction. In this case, the displacement is less in both directions compared with bare frame and in-filled frame.
The effect of blast load is more on top story's of the structure.

The reason behind this is shear wall at bottom has the capability to get hold of all the vibrations raised from the sudden blast explosive load. The present study represents that the provision of shear wall is most efficient technique in resisting blast loads.

5.2 stress contours

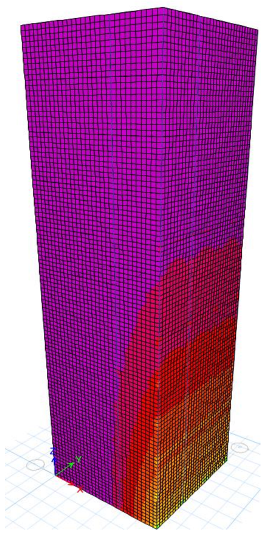


Fig.17. Stress contour of shear wall

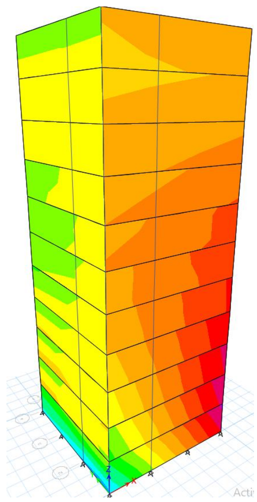


Fig.18. Stress contour of infilled frame

After observation of the above stress contours we can clearly say the maximum stress is occurring at the opposite face to the application load in both the cases. The maximum stress in shear wall case is 5.5 MPa and in infilled frame case maximum stress value is -480 MPa

6. Conclusions

The aim in this research is to know the behaviour of structure under blast or explosion and to protect the overall collapse of the building and very high damages by comparing bare frame and brick masonry as infill, though the fact that, the level of the explosion and the pressure or loads caused by it cannot be found exactly, the most possible situation to find the essential engineering and architectural results.

1. The effect of explosion at top stories is very low compared with the bottom stories
2. The inter storey drifts of a bare frame and in-filled frame goes on increasing from storey 1 to storey 11 in x- direction, as well as maximum drift occurred at storey 1 and goes on decreasing with the storey
3. The reason behind the variation of displacement and inter story drifts is the point and direction of application of load.
4. After comparing the storey drift and displacement of bare frame and masonry infill the study concludes that the structure is more stable or less damaged with the infills in the structure.
5. After observation of the above stress contours we can clearly say the maximum stress is occurring at the opposite face to the application load in both the cases.

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