ANALYTICAL STUDY ON BEHAVIOUR OF STRUCTURE ON EFFECT DUE TO BLASTING LOAD

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Abstract - There was an increase in stability or safety of structure against the terrorist attack in the past decade. Due to attacks there will be threat to life and the structures. In addition, the terrorists are using new chemicals and technology to increase the impact load on the structures. In the recent explosions or terrorists attacks such as Jewish community centre in Argentina (1994), Murrah building in USA (1995), Khobar towers in Saudi Arabia (1996), Colombo world trade centre bombing in Sri Lanka (1997), World trade centre in USA 9/11 (2001), Maoist attack Dantewada, Chhattisgarh in India (2010), Easter bombing in Sri Lanka (2019), etc. had huge number of casualties and destroyed structural system based on effect of charge. Thus finding out the response of a structures subjected to blast load is important and necessary to minimize the effect of blast on structure which not only leads to safety of structure but also reduces the casualties. For the analysis of blast load different cases have been selected. Also the comparison is given for normal reinforced concrete building with bracing and without bracing. Also the structure shape has been changed and compared with normal structure. The analysis is carried out for G+6 storey structure by considering charge type as RDX.

Key Words: Blast load, explosives (rdx) , stand-off distance, storey drift, storey displacement, steel bracings, irregular structure.

1.INTRODUCTION

Blast load is a rapid release of potential energy characterized by a very bright flash released as an audible part of energy is released as thermal radiation (flash) & a part of it is coupled into the air & into the soil such as ground waves. The effects of an explosion are in the form of shock or impact waves, which are composed of very high intensities. These waves expand outward from the source of origin to the surrounding region. As the waves are expanded in the outward region, the strength of waves is reduced based on the distance i,e. as length of waves increases the effect of load decreases on the structure. The effects of blast load are in the form of shock waves which are directly related to stress – wave propagation. The effect of waves varies based on distance between the charge and structure. As the distance of charge increases the effect of the shock wave decreases and vice – versa. The effect of pressure on the structures will be from microseconds to milliseconds. When the blast or explosion occurs based on the charge weight and standoff distance, a sudden release of energy takes place in the atmosphere which leads to blast waves or shock waves. These waves travelling in air along radially are termed as incident waves and those which travel along the ground are termed as reflected waves. Both these waves will travel quickly (high speed). The intensity of the blast wave depends on the nature of explosive material and distance.

2.OBJECTIVES

1. To know the effect of blast load on structure and sudden wave interaction with the structure.
2. To evaluate response mainly displacement of the structure with change in charge and stand-off distance.
3. Different models to be adopted to find the behaviour of structure under blast loads.

3.METHODOLOGY

To find the effect of blast on the structure, the US has developed a technical manual UFC3-340-02. This manual isused for evaluating the blast parameters for different types of blasts, the parameters are used in analysis. The analysis is carried out using SAP2000. The software used is SAP2000 (Structural Analysis Program 2000) which is a product of CSI (Computers & Structures. Inc.). The SAP2000 is civil engineering software used for analysis and design of the structure. The tool bar helps in defining the materials, modelling the structures and also assigning the loads. The software helps to find out the response of a structure with different functions available in it. Also the structural system can be designed. The software consists of a grid system, which can be easily used for modelling. In the present thesis an analysis is carried out for a seven storied reinforced concrete frame structure which consists of 4 bays of 5.5m each in X direction and 4 bays of 4m each in Y direction. The storey height will be restricted to 3.5m. The overall size of the structure is 22 x 16 x 24.5m.

➢ MATERIALS PROPERTIES

1. Concrete grade : M30
2. Grade of steel : Fe415

➢ SECTIONS USED

1. Beam : 250mmX450mm (cover = 30mm)
2. Column : 350mmX450mm (cover = 40mm)
3. Bracing : ISMB 450
4. Thickness of slab : 150mm
5. Thickness of wall : 230mm

➢ LOADS ON STRUCTURE

1. Live load : 3kN/m^2
2. Floor finishes : 1.67kN/m^2 (Assuming 100mm thick)
3. Wall load : 14.14kN/m^2
4. Parapet wall load : 7.31kN/m^2

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➢ PARAMETERS

1. Storey displacement
2. Storey drift

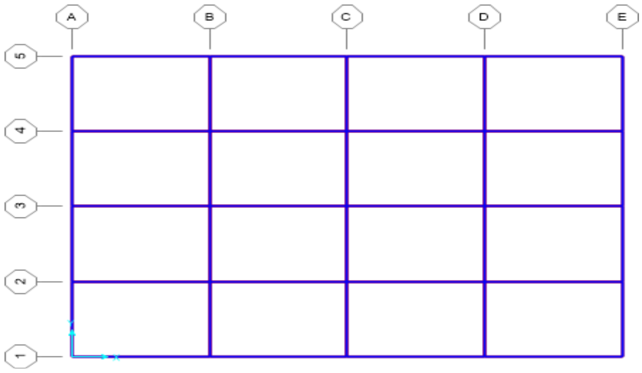


Fig -1: Plan of the structure in x-y plane

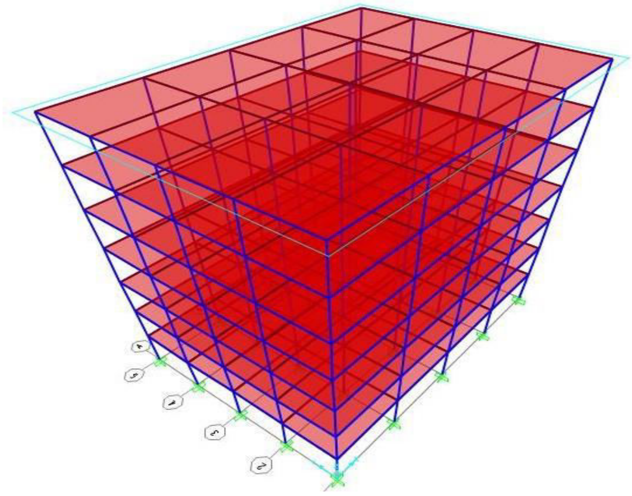


Fig -2: 3D view of the structure

➢ DIFFERENT CASES ARE LISTED BELOW:

1. G+6 storey reinforced concrete structure with 100Kg RDX (118.58Kg TNT), stand- off distance varied from 10m to 60m with intervals of 10 m each.
2. G+6 storey reinforced concrete structure including bracings with 100Kg RDX (118.58Kg TNT), stand-off distance varied from 10m to 60m with intervals of 10 m each.
3. G+6 storey reinforced concrete structure with 100Kg RDX (118.58Kg TNT), 250Kg RDX (296.46Kg TNT), 500Kg RDX (592.92Kg TNT) at a stand-off distance of 10m**.**
4. G+6 storey reinforced concrete ir-regular structure with 100Kg RDX (118.58Kg TNT), 250Kg RDX (296.46Kg TNT), 500Kg RDX (592.92Kg TNT) at a stand-off distance of 10m**.**

➢ The blast load calculation of 100kg charge at 10m stand-off distance is shown below which was used for analysis purpose:

1. Charge weight (w) = 100Kg RDX

(w) = 100 x (53604520)= 118.58Kg of TNT
(w) = 118.58 x 2.2046 = 261.43 lb TNT
(W) = 261.43 x 1.2 = 313.716 lb TNT (increasing 20%)

2. Stand-off distance **RG** = 10 x 3.28 = 32.8ft

3. Scaled distance **ZG** = 32.8313.71613 = 4.827ft/lb(13)

4. Find the blast load parameters for the obtained scaled distance from figure 2-15 pg no. 90 of UFC-3-340-02. The different blast load parameters are listed below :

- Peak positive pressure (***PSO***) = 50 Psi
- Arrival time (***tA***) = 8.153 ms
- Positive phase duration (***tO***) = 11.551 ms
- Positive incident impulse (***iS***) = 122.30 psi-ms

5. Front wall reflected pressure and impulse:

Read Reflected pressure co-efficient **(Crα)** from figure 2-193 pg 268 of UFC-3-340-02 for obtained ***PSO*** at Angle of incidence **(α) = 0**, **Crα = 4 ,**

- Reflected pressure **(Prα) = Crα *** ***PSO***
  Prα = 4 x 50 = 200 Psi

Read impulse **(irα)** from figure 2-194(a) pg no.269 of UFC-3-340-02 for obtained ***PSO*** at **α = 0**

- Impulse **irα** = 251.42 Psi

6. Front wall loading for positive phase:

- Calculate sound velocity **(Cr)** in reflected over pressure region from figure 2-192 pg no.267 of UFC-3-340-02 for obtained ***PSO***.
  Cr = 1.76 ft/ms
- Calculate clearing time ***tC***
  tC*=4*S*(1+*R*)*Cr
  tC = 4∗36.08(1+0.4489)∗1.76 = 56.59 ms
- Fictitious positive phase :
  tof*=2∗*isPso
  tof = 2∗122.3050 = 4.89 ms
- Peak dynamic pressure **qo** from figure 2-3 pg no.79 of UFC 3-340-02 for obtained *PSO*
  qo = 40 Psi

7. Fictitious duration of reflected pressure :
trf = 2 * ir**α** / Pr**α**
trf = 2∗(251.42200) = 90 Psi

8. Pressure on front wall:

P = *PSO* + CD * qo

P = 50+ (1 x 40) = 90 Psi
P = 90 x 6.89 = 620.1kN/m2
Therefore load on each node = {620.01 x (5.5 x 3.5)}/4
= 2983.75kN

➢ APPLICATION OF LOADS FOR DIFFERENT CASES:

The load is in the form of point load, this load can be applied on the face of the building.

A. G+6 storey reinforced concrete structure with 100Kg RDX (118.58Kg TNT), stand- off distance varied from 10m to 60m with intervals of 10 m each.

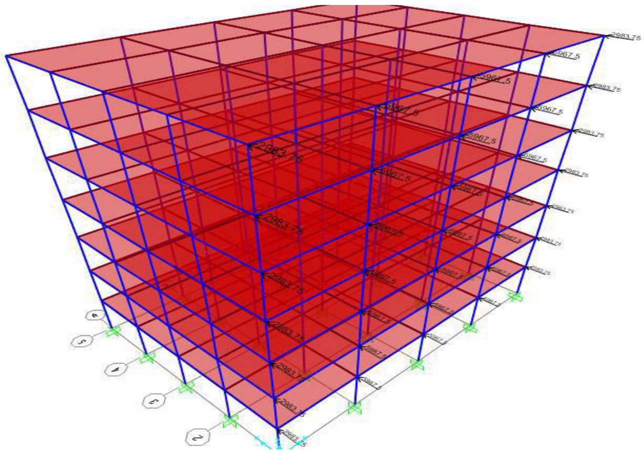


Fig -3: Blast load for 100kg @ 10m Stand-off distance.

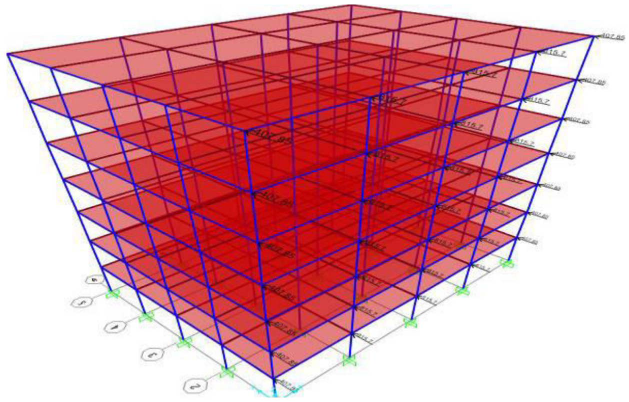


Fig -4: Blast load for 100kg @ 20m Stand-off distance.

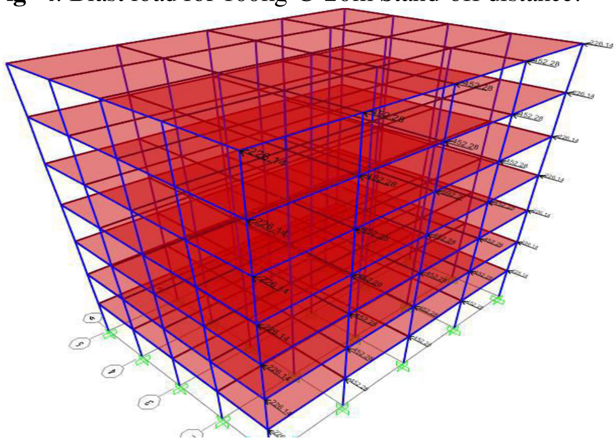


Fig -5: Blast load for 100kg @ 30m Stand-off distance.

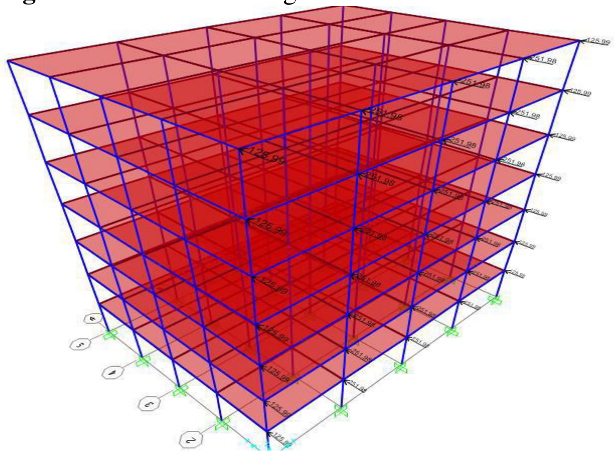


Fig -6: Blast load for 100kg @ 40m Stand-off distance.

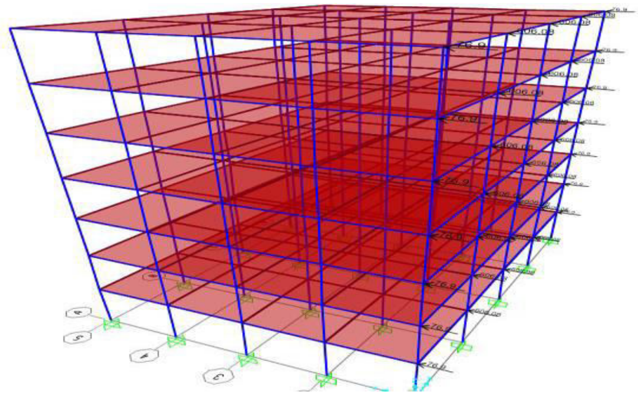


Fig -7: Blast load for 100kg @ 50m Stand-off distance.

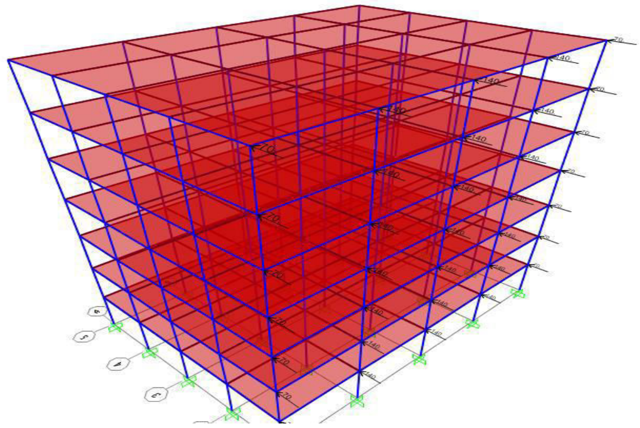
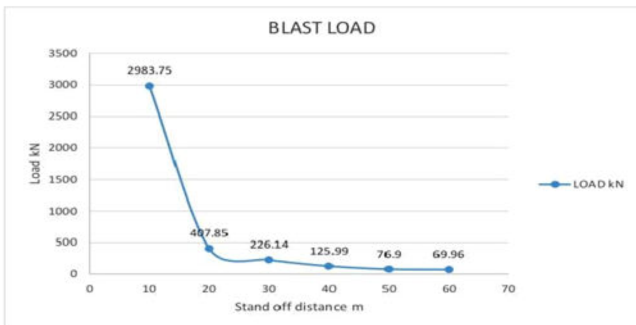


Fig -8: Blast load for 100kg @ 60m Stand-off distance.

Table -1: Blast load for different stand-off distance for 100kG rdx

STANDOFF DISTANCE m	LOAD kN
10	2983.75
20	407.85
30	226.14
40	125.99
50	76.9
60	69.96

Graph :1 Blast load variation for different stand-off distance for 100kG rdx



B. G+6 storey reinforced concrete structure including bracings with 100Kg RDX (118.58Kg TNT), stand-off distance varied from 10m to 60m with intervals of 10 m each.

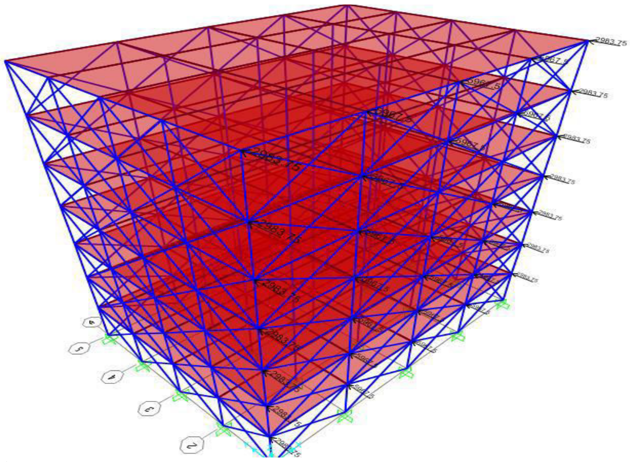


Fig -9: Blast load for 100kg @ 10m Stand-off distance with bracings.

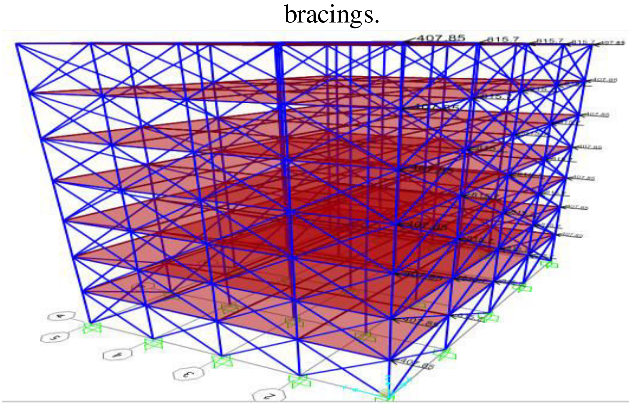


Fig -10: Blast load for 100kg @ 20m Stand-off distance with bracings.

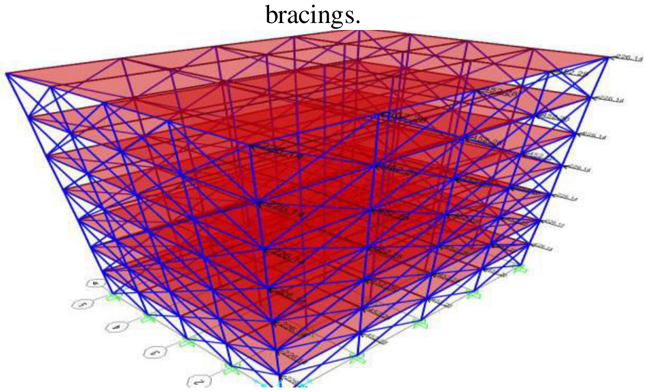


Fig -11: Blast load for 100kg @ 30m Stand-off distance with bracings.

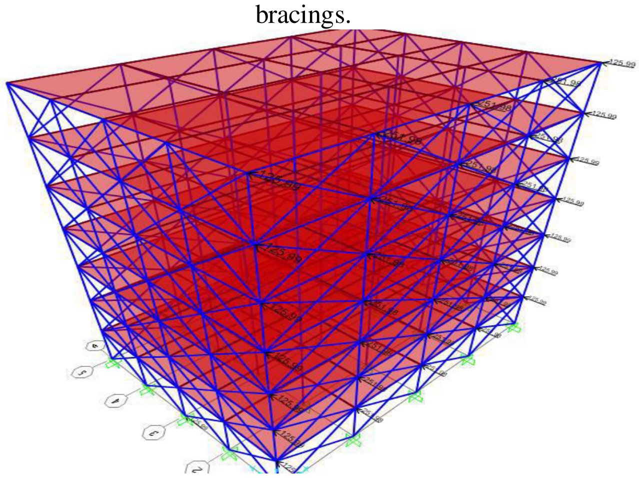


Fig -12: Blast load for 100kg @ 40m Stand-off distance with bracings.

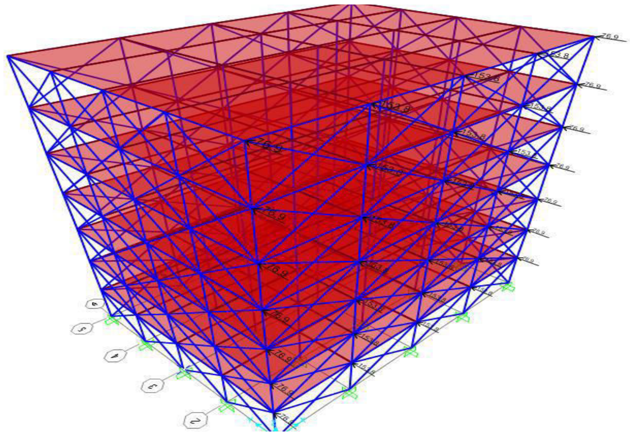


Fig -13: Blast load for 100kg @ 50m Stand-off distance with bracings.

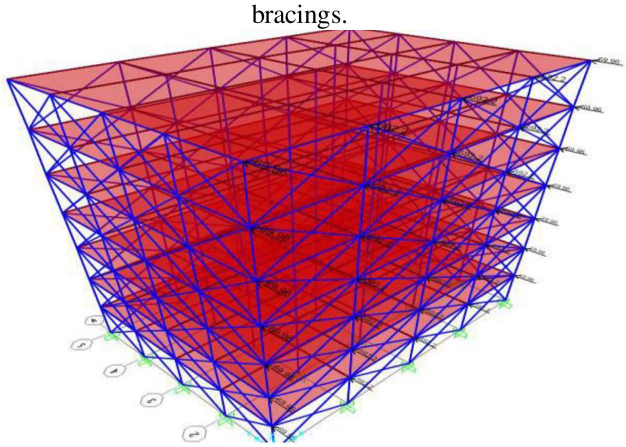


Fig -14: Blast load for 100kg @ 60m Stand-off distance with bracings.

C. G+6 storey reinforced concrete ir-regular structure with 100Kg RDX (118.58Kg TNT), 250Kg RDX (296.46Kg TNT), 500Kg RDX (592.92Kg TNT) at a stand-off distance of 10m**.**

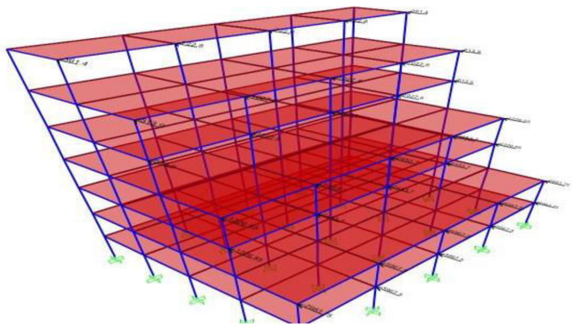


Fig -15: Blast load for irregular structure 100kg RDX @ 50m Stand-off distance

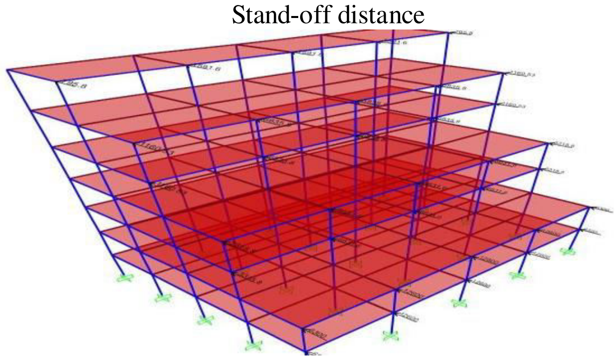


Fig -16: Blast load for irregular structure 250kg RDX @ 50m Stand-off distance

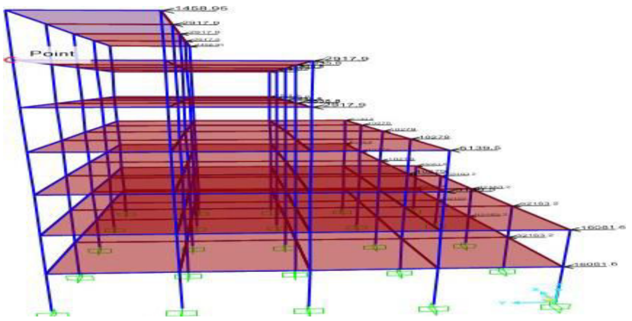
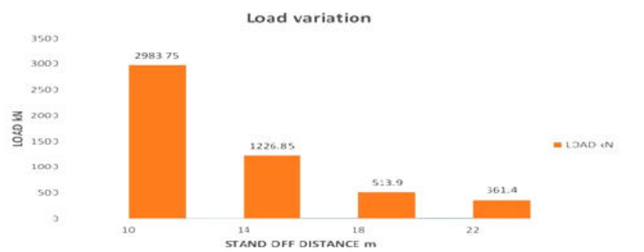


Fig -17: Blast load for irregular structure 500kg RDX @ 50m Stand-off distance

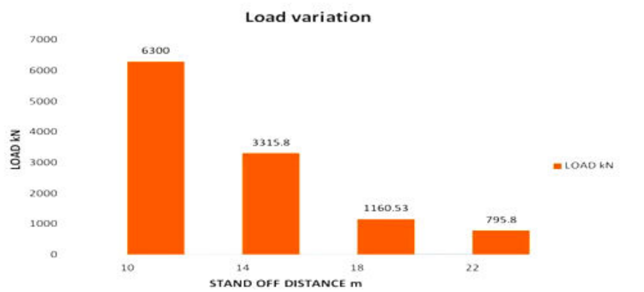
Table -2: Blast load for irregular structure different for 100Kg, 250Kg and 500Kg RDX at 10m stand-off distance

STANDOFF DISTANCE (m)	LOAD kN		
	100Kg RDX	250Kg RDX	500Kg RDX
10	2983.75	6300	16081.6
14	1226.85	3315.8	5139.5
18	513.9	1160.53	2917.9
22	361.4	795.8	1458.95

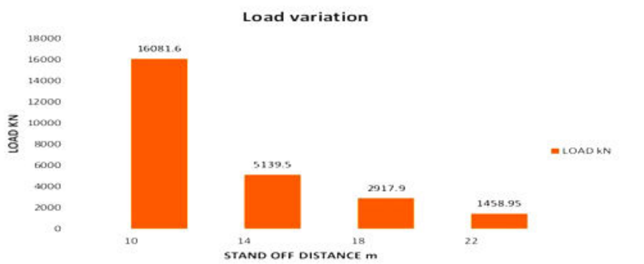
Graph :2 Blast load for irregular structure for 100Kg RDX at 10m stand-off distance



Graph :3 Blast load for irregular structure for 250Kg RDX at 10m stand-off distance



Graph :4 Blast load for irregular structure for 500Kg RDX at 10m stand-off distance



4. RESULTS AND DISCUSSION:

The results obtained from the SAP 2000 is reported as below. The analysis results gives the idea of response of a structure. To find the response, the displacement is considered in the direction of application of blast load. With the help of displacement the story drift is calculated and plotted. To reduce the displacement that is to increase the stability of the structure the bracings are provided. The comparison of the effect of blast load for the ir-regular structure is done. For all these cases the results are taken from the software.

➢ **DISPLACEMENT & STOREY DRIFT:**
For the different cases the displacement and storey drifts are shown below. Also the storey drift is checked with acceptable limits by using IS 1893 2002

A. G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 10m:

Table 3 shows the displacement versus storey of structure. From the analysis the results obtained are tabulated in **table 3** which shows that the displacement increases as the height of storey increases. It is seen that the displacement is maximum at the top of the storey, for structure without bracings the displacement at top is 2.85m where as for structures with bracings the displacement at top is 0.462m for ISMB 250, 0.294m for ISMB 450 and 0.265m for ISMB 500. **Graph 5** shows that the structures with bracings resists more blast load compared to normal structure. **Table 4** shows the storey drift versus storey of structure. **Graph 6** shows that the structure without bracing has a maximum drift at 2nd storey and structure with bracing has a maximum drift at 1st storey. This is due to travelling of blast waves at ground surface. It is observed that the structure with bracing resists maximum lateral load. This may be probably due to increase in moment of inertia of the structure. As per IS: 1893 2002, the maximum storey drift is 0.004*h (h is the height of the storey), that is for this structure 14mm. From the analysis the maximum storey drift at 2nd level was 180mm which is higher when compared to the codal provisions. Hence this structure is unsafe, to obtain the safe structure a new model was analysed with X bracing of ISMB 450, still the drift was found to be 14.88mm which is unsafe. To satisfy the storey drift and understand the behaviour of structure, two more models were introduced with bracing ISMB 250 and ISMB 500. The analysis results showed that the maximum storey drift for ISMB 250 and ISMB 500 are 25.22mm and 13.18mm respectively. The results showed that for ISMB 500 the storey drift was well within permissible limits. It was seen that out of 455 members in the structure, the structure without bracing all the members were failed. Whereas structure with bracing the number of members failed were 403 for ISMB 250, 346 for ISMB 450 and 326 for ISMB 500.

Table -3 Displacement of structure with bracing and without bracing for 100kg rdx at 10m stand-off distance.

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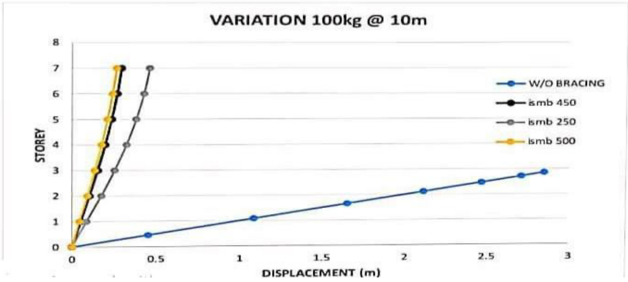
DISPLACEMENT					
FLOOR	JOINT	WITHOUT BRACING (m)	ISMB 250 (m)	ISMB 450 (m)	ISMB 500 (m)
BASE	0	0	0	0	0
GROUND FLOOR	1	0.454753	0.085763	0.051411	0.045632
STOREY 1	2	1.086794	0.174055	0.103506	0.091783
STOREY 2	3	1.651712	0.253642	0.152481	0.135659
STOREY 3	4	2.113843	0.323451	0.197061	0.175981
STOREY 4	5	2.467126	0.382009	0.235974	0.211532
STOREY 5	6	2.710576	0.428394	0.268428	0.241549
STOREY 6	7	2.850071	0.462257	0.294102	0.265724

Table -4 Storey drift of structure with bracing and without bracing for 100kg rdx at 10m stand-off distance.

STOREY DRIFT 10-3				
FLOOR	WITHOUT BRACING	ISMB 250	ISMB 450	ISMB 500
BASE	0	0	0	0
GROUND FLOOR	0.129929	0.0245037	0.014689	0.013038
STOREY 1	0.180583	0.0252262	0.014884	0.013186
STOREY 2	0.161405	0.0227391	0.013993	0.012536
STOREY 3	0.132037	0.0199454	0.012737	0.011521
STOREY 4	0.100938	0.0167308	0.011118	0.010157
STOREY 5	0.069557	0.0132528	0.009273	0.008576
STOREY 6	0.039856	0.0096751	0.007335	0.006907

Graph: 5 Variation of displacement with bracing and without bracing for 100kg rdx at 10m stand-off distance.



Graph :6 Variation of storey drift with bracing and without bracing for 100kg rdx at 10m stand-off distance.

B. G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 20m:

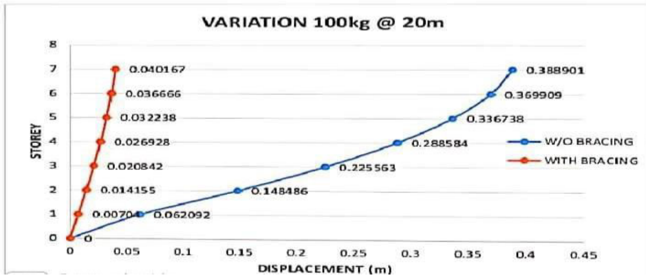
Table 5 shows the displacement and storey drift versus storey of structure. From the analysis the results obtained are tabulated in **table 5** which shows that the displacement increases as the height of storey increases. It is seen that the displacement is maximum at the top of the storey, for structure without bracings the displacement at top is 0.3889m where as for structures with bracings the displcement at top is 0.04016m for ISMB 450. **Graph 7** shows that the structures with bracings resists more blast load compared to normal structure.

Graph 8 shows that the structure without bracing has a maximum drift at 2nd storey and structure with bracing has a maximum drift at 1st storey. From the analysis the maximum storey drift at 2nd level was 24.68mm which is higher when compared to the codal provisions. Hence this structure is unsafe, to obtain the safe structure a new model was analysed with X bracing of ISMB 450, the drift was found to be 2.032mm which is safe. The results showed that for ISMB 450 the storey drift was well within permissible limits. It was seen that out of 455 members in the structure, the structure without bracing the members failed were 376. Where as structure with bracing the number of members failed were 4 for ISMB 450.

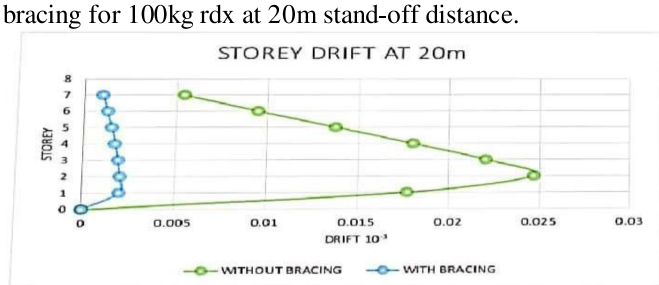
Table -5 Displacement and storey drift of structure with bracing and without bracing for 100kg rdx at 20m stand-off distance.

DISPLACEMENT				STOREY DRIFT 10-3	
	JOINT	WITHOUT BRACING (m)	BRACING(m)	WITHOUT BRACING	BRACING
BASE	0	0	0	0	0
GROUND FLOOR	1	0.062092	0.00704	0.01774057	0.00201142
STOREY 1	2	0.148486	0.014155	0.024684	0.00203285
STOREY 2	3	0.225563	0.020842	0.022022	0.00191057
STOREY 3	4	0.288584	0.026928	0.018006	0.00173885
STOREY 4	5	0.336738	0.032238	0.01375828	0.00151714
STOREY 5	6	0.369909	0.036666	0.00947742	0.00126514
STOREY 6	7	0.388901	0.040167	0.00542628	0.00100028

Graph :7 Variation of displacement with bracing and without bracing for 100kg rdx at 20m stand-off distance.



Graph:8 Variation of storey drift with bracing and without bracing for 100kg rdx at 20m stand-off distance.



C. G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 30m:

Table 6 shows the displacement and storey drift versus storey of structure. From the analysis the results obtained are tabulated in **table 6** which shows that the displacement increases as the height of storey increases. It is seen that the displacement is maximum at the top of the storey, for structure without bracings the displacement at top is 0.2156m where as for structures with bracings the displcement at top is 0.02349m for ISMB 450. **Graph 9** shows that the structures with bracings resists more blast load compared to normal

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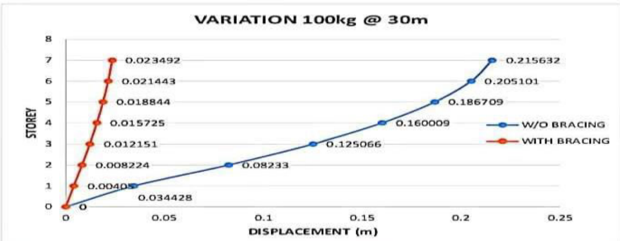
structure. **Graph 10** shows that the structure without bracing has a maximum drift at 2nd storey and structure with bracing has a maximum drift at 1st storey. From the analysis the maximum storey drift at 2nd level was 13.68mm which is safe when compared to the codal provisions. Hence this structure is safe, now the structure was analysed with X bracing of ISMB 450, the drift was found to be 1.192mm which is safe. The results showed that for both the structures the storey drift was well within permissible limits. It was seen that out of 455 members in the structure, the structure without bracing the members failed were 304. Where as structure with bracing no members were failed.

Table -6 Displacement and storey drift of structure with bracing and without bracing for 100kg rdx at 30m stand-off distance.

	DISPLACEMENT			STOREY DRIFT 10-3	
	JOINT	WITHOUT BRACING (m)	BRACING (m)	WITHOUT BRACING	BRACING
BASE	0	0	0	0	0
GROUND FLOOR	1	0.034428	0.00405	0.009836571	0.001157143
STOREY 1	2	0.08233	0.008224	0.013686286	0.001192571
STOREY 2	3	0.125066	0.012151	0.012210286	0.001122
STOREY 3	4	0.160009	0.015725	0.009983714	0.001021143
STOREY 4	5	0.186709	0.018844	0.007628571	0.000891143
STOREY 5	6	0.205101	0.021443	0.005254857	0.000742571
STOREY 6	7	0.215632	0.023492	0.003008857	0.000585429

Graph:9 Variation of displacement with bracing and without bracing for 100kg rdx at 30m stand-off distance.



Graph:10 Variation of storey drift with bracing and without bracing for 100kg rdx at 30m stand-off distance.

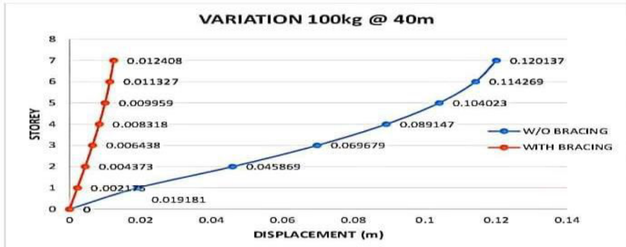
D. G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 40m:

Table 7 shows the displacement and storey drift versus storey of structure. From the analysis the results obtained are tabulated in **table 7** which shows that the displacement increases as the height of storey increases. It is seen that the displacement is maximum at the top of the storey, for structure without bracings the displacement at top is 0.1201m where as for structures with bracings the displcement at top is 0.01240m for ISMB 450. **Graph11** shows that the structures with bracings resists more blast load compared to normal structure. **Graph12** shows that the structure without bracing has a maximum drift at 2nd storey and structure with bracing has a maximum drift at 1st storey. From the analysis the maximum storey drift at 2nd level was 7.625mm which is safe when compared to the codal provisions. Hence this structure is safe, now the structure was analysed with X bracing of ISMB 450, the drift was found to be 0.628mm which is safe.
The results showed that for both the structures the storey drift was well within permissible limits. It was seen that out of 455 members in the structure, the structure without bracing the members failed were 183. Where as structure with bracing no members were failed.

Table -7 Displacement and storey drift of structure with bracing and without bracing for 100kg rdx at 40m stand-off distance.

	DISPLACEMENT			STOREY DRIFT 10-3	
	JOINT	WITHOUT BRACING (m)	BRACING (m)	WITHOUT BRACING	BRACING
Base.	0	0	0	0	0
GROUND FLOOR	1	0.019181	0.002175	0.005480286	0.000621429
STOREY 1	2	0.045869	0.004373	0.007625143	0.000628
STOREY 2	3	0.069679	0.006438	0.006802857	0.00059
STOREY 3	4	0.089147	0.008318	0.005562286	0.000537143
STOREY 4	5	0.104023	0.009959	0.004250286	0.000468857
STOREY 5	6	0.114269	0.011327	0.002927429	0.000390857
STOREY 6	7	0.120137	0.012408	0.001676571	0.000308857

Graph:11 Variation of displacement with bracing and without bracing for 100kg rdx at 40m stand-off distance.



Graph:12 Variation of storey drift with bracing and without bracing for 100kg rdx at 40m stand-off distance.

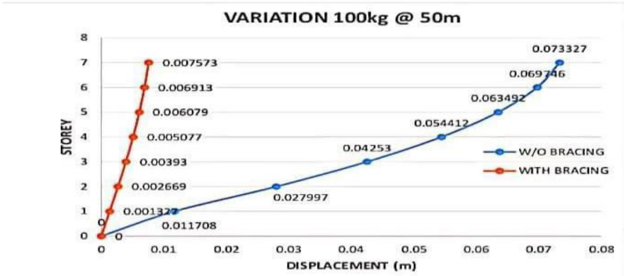
E. G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 50m:

Table 8 and **9** shows the displacement and storey drift versus storey of structure. From the analysis the results obtained are tabulated in **table 8** and **9** which shows that the displacement increases as the height of storey increases. **Graph 14** and **16** shows that the structure without bracing has a maximum drift at 2nd storey and structure with bracing has a maximum drift at 1st storey. From the analysis the maximum storey drift at 2nd level was 4.65mm and 4.23mm for 50 and 60m stand-off distance respectively, which is safe when compared to the codal provisions. Hence this structure is safe, now the structure was analysed with X bracing of ISMB 450, the drift was found to be 0.383mm and 0.348mm for 50 and 60m stand-off distance respectively, which is safe. The results showed that for both the structures the storey drift was well within permissible limits. It was seen that out of 455 members in the structure, the structure without bracing the members failed were 43 and 10 for 50 and 60m respectively. Where as structure with bracing no members were failed.

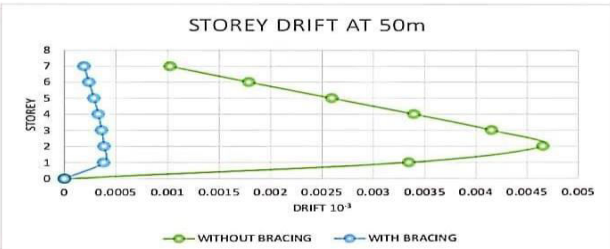
Table -8 Displacement and storey drift of structure with bracing and without bracing for 100kg rdx at 50m stand-off distance.

	DISPLACEMENT			STOREY DRIFT10-3	
	JOINT	WITHOUT BRACING (m)	BRACING (m)	WITHOUT BRACING	BRACING
BASE	0	0	0	0	0
GROUND FLOOR	1	0.011708	0.001327	0.003345143	0.000379143
STOREY 1	2	0.027997	0.002669	0.004654	0.000383429
STOREY 2	3	0.04253	0.00393	0.004152286	0.000360286
STOREY 3	4	0.054412	0.005077	0.003394857	0.000327714
STOREY 4	5	0.063492	0.006079	0.002594286	0.000286286
STOREY 5	6	0.069746	0.006913	0.001786857	0.000238286
STOREY 6	7	0.073327	0.007573	0.001023143	0.000188571

Graph:13 Variation of displacement with bracing and without bracing for 100kg rdx at 50m stand-off distance.



Graph :14 Variation of storey drift with bracing and without bracing for 100kg rdx at 50m stand-off distance.

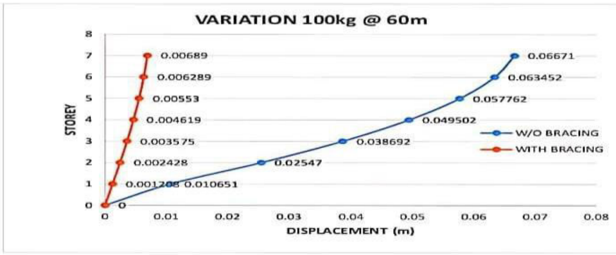


F. G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 30m:

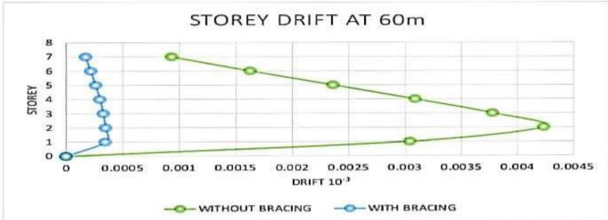
Table -9 Displacement and storey drift of structure with bracing and without bracing for 100kg rdx at 60m stand-off distance.

	DISPLACEMENT			STOREY DRIFT 10-3	
	JOINT	WITHOUT BRACING (m)	BRACING (m)	WITHOUT BRACING	BRACING
BASE	0	0	0	0	0
GROUND FLOOR	1	0.010651	0.001208	0.003043143	0.0003 45143
STOREY 1	2	0.02547	0.002428	0.004234	0.0003 48571
STOREY 2	3	0.038692	0.003575	0.003777714	0.0003 27714
STOREY 3	4	0.049502	0.004619	0.003088571	0.0002 98286
STOREY 4	5	0.057762	0.00553	0.00236	0.0002 60286
STOREY 5	6	0.063452	0.006289	0.001625714	0.0002 16857
STOREY 6	7	0.06671	0.00689	0.000930857	0.0001 71714

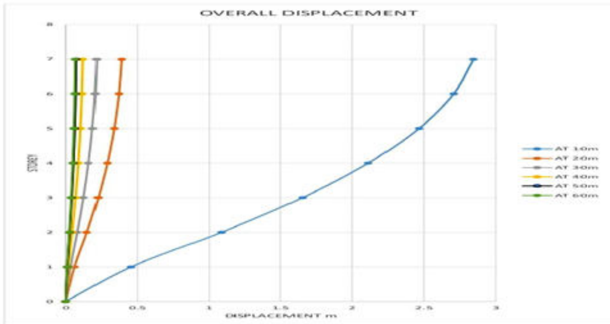
Graph:15 Variation of displacement with bracing and without bracing for 100kg rdx at 60m stand-off distance.



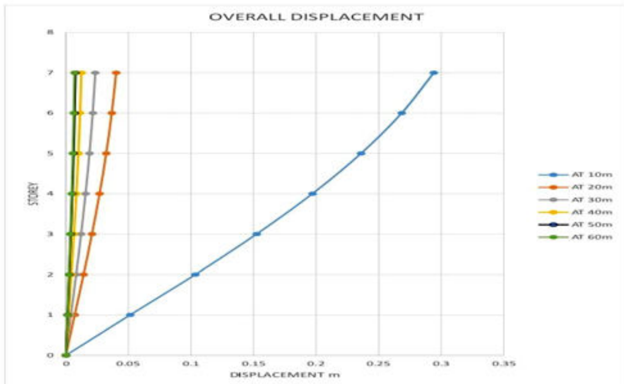
Graph:16 Variation of storey drift with bracing and without bracing for 100kg rdx at 60m stand-off distance.



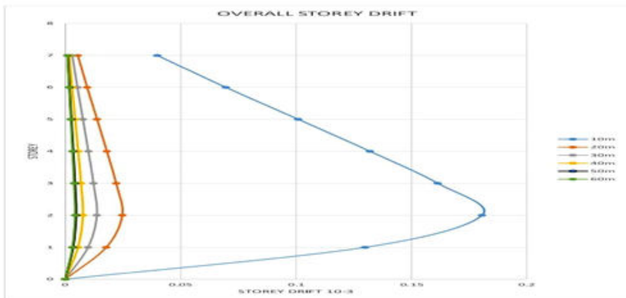
Graph:17 Comparison of displacement for structure without bracing for all stand-off distance



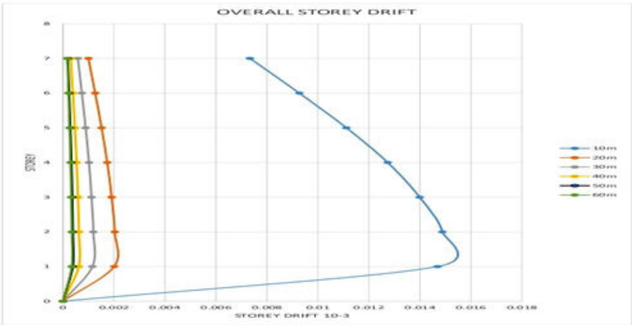
Graph:18 Comparison of displacement for structure with bracing for all stand-off distance



Graph:19 Comparison of storey drift for structure without bracing for all stand-off distance



Graph:20 Comparison of storey drift for structure with bracing for all stand-off distance



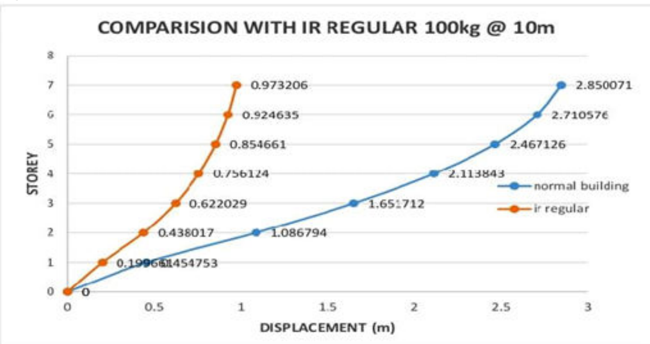
G. Displacement for ir-regular structure for 100Kg, 250Kg and 500Kg RDX at 10m Stand-off distance:

The structure was compared with irregular structure and analysed to obtain results. The results obtained are tabulated and comparison is given below. **Graph 21** shows that the displacement reduces as the shape of the structure is changed. The displacement at top story for normal building is 2.85m where as for irregular structure it is 0.973m. **Table 10** shows the storey drift, for normal structure the maximum storey drift is 180mm and for irregular structure the maximum story drift is 68.1mm.

Table -10 Displacement and storey drift for normal and ir-regular structure for 100kg rdx at 10m

	DISPLACEMENT			STOREY DRIFT 10-3	
	JOINT	NORMAL STRUCTURE (m)	IR-REGULAR STRUCTURE (m)	NORMAL STRUCTURE	IR-REGULAR STRUCTURE
BASE	0	0	0	0	0
GROUND FLOOR	1	0.454753	0.199661	0.129929429	0.057046
STOREY 1	2	1.086794	0.438017	0.180583143	0.068101714
STOREY 2	3	1.651712	0.622029	0.161405143	0.052574857
STOREY 3	4	2.113843	0.756124	0.132037429	0.038312857
STOREY 4	5	2.467126	0.854661	0.100938	0.028153429
STOREY 5	6	2.710576	0.924635	0.069557143	0.019992571
STOREY 6	7	2.850071	0.973206	0.039855714	0.013877429

Graph:21 Comparison of displacement for normal and ir-regular structure for 100kG rdx at 10M



Graph:22 Comparison of story drift for normal and ir- regular structure for 100kG rdx at 10M

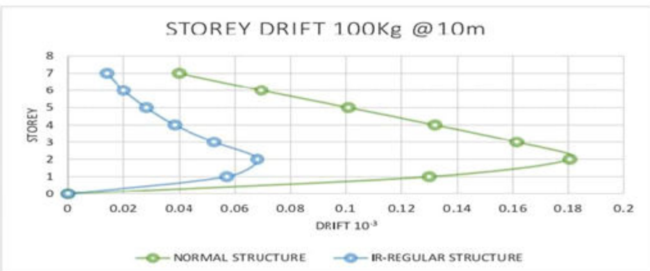
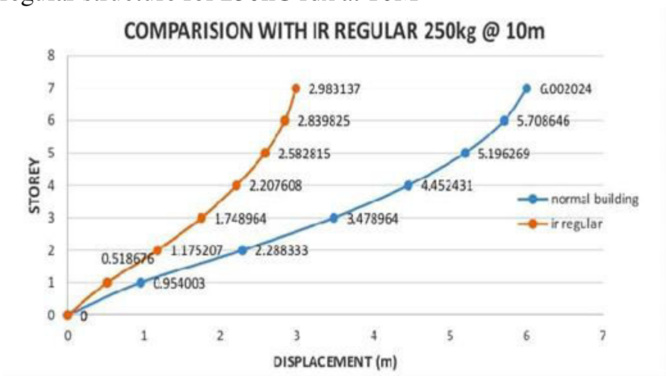


Table -11 Displacement and storey drift for normal and ir-regular structure for 250kg rdx at 10m

	DISPLACEMENT (m)			STOREY DRIFT 10-3	
	JOINT	NORMAL STRUCTURE	IR-REGULAR STRUCTURE	NORMAL STRUCTURE	IR-REGULAR STRUCTURE
BASE	0	0	0	0	0
GROUND FLOOR	1	0.954003	0.518676	0.272572286	0.148193143
STOREY 1	2	2.288333	1.175207	0.381237143	0.187580286
STOREY 2	3	3.478964	1.748964	0.340180286	0.163930571
STOREY 3	4	4.452431	2.207608	0.278133429	0.131041143
STOREY 4	5	5.196269	2.582815	0.212525143	0.107202
STOREY 5	6	5.708646	2.839825	0.146393429	0.073431429
STOREY 6	7	6.002024	2.983137	0.083822286	0.040946286

Graph:23 Comparison of displacement for normal and ir-regular structure for 250kG rdx at 10M

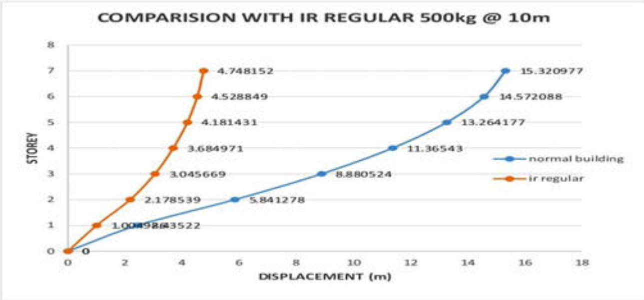


Graph:24 Comparison of story drift for normal and ir- regular structure for 250kG rdx at 10M

Table -12 Displacement and storey drift for normal and ir-regular structure for 500kg rdx at 10m

	DISPLACEMENT (m)			STOREY DRIFT 10-3	
	JOINT	NORMAL STRUCTURE	IR-REGULAR STRUCTURE	NORMAL STRUCTURE	IR-REGULAR STRUCTURE
BASE	0	0	0	0	0
GROUND FLOOR	1	2.43522	1.004986	0.695777143	0.287138857
STOREY 1	2	5.841278	2.178539	0.973159429	0.335300857
STOREY 2	3	8.880524	3.045669	0.868356	0.247751429
STOREY 3	4	11.36543	3.684971	0.709973143	0.182657714
STOREY 4	5	13.264177	4.181431	0.542499143	0.141845714
STOREY 5	6	14.572088	4.528849	0.373688857	0.099262286
STOREY 6	7	15.320977	4.748152	0.213968286	0.062658

Graph:25 Comparison of displacement for normal and ir-regular structure for 500kG rdx at 10M



Graph:26 Comparison of story drift for normal and ir- regular structure for 500kG rdx at 10M

For the case of 100Kg at 10m the maximum storey drift for irregular structure is 68.1mm from **table 10**. For 250Kg and 500Kg at 10m the maximum storey drift for irregular structure is 187.5mm from **table 11** and 335.3mm from **table 12**. It was seen that all the members of irregular structure that is 329 members were failing for all the cases.

5. CONCLUSIONS

1. Determination of blast load describes for the selected cases that as the stand of distance increases the blast load decreases. From results it indicates that blast load is very high at 10m stand-off distance.
2. If the standoff distance is very near to the structure, then the displacements and storey drifts are very high and are not satisfying permissible storey drift as described in IS1893-2002. The failure of structural members is too high.
3. Storey drifts were high at lower storey that describes the effect of blast load is more due to nearer the detonation point and travelling of shockwaves at ground.
4. When bracings are added to the structure, the displacements and storey drift reduces to very high percentage. The failure of structural members is reduced very highly.
5. When bracings are added it was seen that for 20m stand-off distance the obtained storey drift was 2.032mm which is well within permissible limits that is 14mm for the selected structure. Hence we can say that the safe stand-off distance for structures with bracing is for 20m for ISMB 450,when ISMB 500 is used, it is seen that the drift obtained is 13.18mm that is safe, therefore safe standoff distance obtained is at10m.
6. It is seen that when braces of ISMB 450 were added to the structure, the number of failure of structural members were 0 at stand-off distance of 30m and soon.
7. The value of drift is maximum at second storey in normal structure and at first storey when braces are added this may be probably due to increase in moment of inertia of the structure
8. Considering the irregular shape of the building it indicates that the blast load was decreasing due to irregularity of the building.
9. Comparing the displacements and storey drift to normal structure it is seen that the displacement and storey drift were less compared to normal structure.
10. From over-all it is concluded that the structures with bracings shows high resistance to structure.
11. Comparing normal structure with irregular structure it is seen that irregular structure resists more load.

FUTURE SCOPE

1. The analysis should be carried out with different software such as ABAQUS,L-S DYNA, ANSYS, FLEX, etc for accurate results which gives response with respect to time.
2. The blast load has to be applied on the total face of the wall in analysis process.
3. Effect with respect to aerial blast to be evaluated.
4. Effect of blast load on different shapes such as concave and convex structures to be evaluated.
5. Effect of glazing and spall has to be evaluated.
6. By increasing the size of structural members such as beams and columns and its response to be evaluated.
7. Effect of blast load should be calculated by considering even the height in which load acts radially.
8. Effect has to be evaluated practically since very less data to compare with real time results.

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