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Analysis of G+5 RC Building for Blast Forces

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Abstract: ***Necessity of designing certain important structures to resist blast loads is gaining significance day by day due to increase in Blast attacks by terrorists, and domestic accidents like LPG gas cylinder bursts have become a concern due to their increased rate of recurrence and fatal effect on lives and properties. So it has been a essential to design structures which can resist blast effect better, so that destruction is controlled in a better way Blast forces causes loss of structural integrity due to partial or complete collapse of structural members. Blast loads are dynamic loads that must be calculated cautiously as that of other dynamic loads. The present study presents effect of blast loads on 5 storey R.C.C building. Effect of 100kg Tri nitro toluene (TNT) blast source which is at 40m away from the building is considered for analysis and designed. Blast loads are calculated by hand as per IS: 4991-1968 and force time history analysis is performed in STAAD Pro. The influence of blast loads on structure is compared to that of same structure in static condition, the parameters like peak displacements, velocity, acceleration are considered and the revision in design is made for the structure in static condition so that it can withstand the effect of blast forces.***

Keywords: Blast, Drag- load, Side-on over pressure force, Structural Displacements, Peak reflected overpressure

1. Introduction

Blast resistant deign is a matter of interest for structural engineers these days hence becoming popular in the field of structural engineering. Since there are a number of terror attacks were faced in the society even fire accidents and arsons there is a very much need of this subject to emerge. Many government and some private building owners today require that new buildings be designed to resist the effects of potential blasts and other incidents that could cause tremendous local damage.

Fortunately, the probability that any single building will actually be subjected to such hazards is quite low. As a result, a performance based approach to design has evolved. The most regular performance goals are to permit severe and even tremendous damage should blasts or any other such incidents affect a structure, but avoid huge loss of life.

Structures designed to resist the effects of explosives and impact are permitted to contribute all of their resistance, both material linear (elastic) and material non-linear (inelastic), to absorb damage locally, so as not to compromise the integrity of entire structure. It is likely that local failure can and may be designed to occur, due to uncertainty associated with such blast-loads.

2. Plan and Configurations

The building for the present work is G+5 residential building consisting of 4-bays in Z-direction and an overall span of 15.5m and 17m in X-direction. The typical storey height is 3m and overall height of the building is 18m from the ground level. The following are the specifications of G+5 building in preliminary design. The present blast source was taken as 100 KG TNT at a distance of 40m from the Building as mentioned in IS:4991:1968

Height of floor	: 3.2 m each
Slab thickness	: 125mm
Thickness of wall	: 230mm (outer)
	: 115mm (inner)
Beam sizes	: 230mm x 300mm
Column sizes	: 230mmx600mm (Varies)
Materials	: Grade of steel 415 HYSD
Grade of concrete –	: M25
Density on concrete : 25 kN/m^3	
Live loads on floors	: 2 kN/m^2 for general rooms
	: 3 kN/m^2 for corridors
Live load on roof	: 1.5 kN/m^2
Dead load	: 13 kN/m^2 for outer walls
	: 7.5 kN/m^2 for inner walls
	: 4.7 kN/m^2 for slab dead
load including floor Finishes	
Density of wall	: 19 kN/m^3
Combination load	: 1.5 (Dead load+Live load)
	: 1.2 (Dead load+Live load)

3.1.1 Plan of building

The plan for the present study is G+5 storied building and preliminary design is done by doing static analysis i.e., only dead and live loads of the building are considered for analysis.

Figure 1: Plan of the building

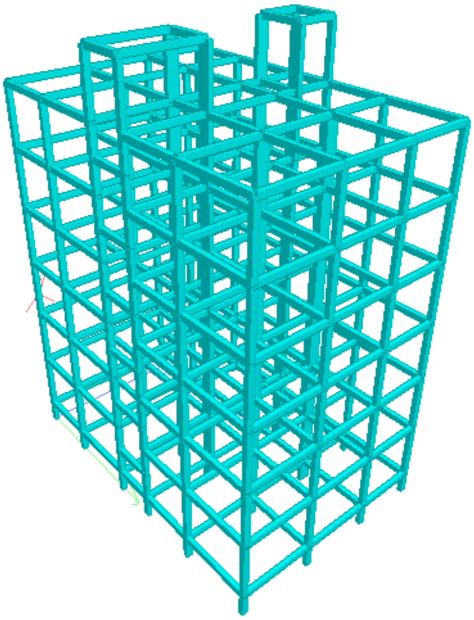


Figure 2: 3-D Rendered view of the building modelled in STAAD Pro

3. Methodology

The beam and columns are modelled in STAAD Pro according to the architectural plan give above and the initial design is done by assuming preliminary dimensions. After the sizing of structural members got confirmed then the Blast forces are calculated manually as per the prescribed IS:4991:1968 see Table.2 and applied on the structure in the form of Pseudo static force on the structure which was designed preliminarily and the results were observe red and the design is modified in-order to make the structure resistant to the forces due to the explosion occured. The distance from the blast source to the point of interest on the building is calculated by using the mathematical formula and tabulated below

$$(X,Y,Z)= \sqrt{(X_2-X_1)^2+(Y_2-Y_1)^2+(Z_2-Z_1)^2} \text{.....(1)}$$

Table 1: Distance from blast source to the target point

Coordinates of point of intrest			Distance between source and point	Scaled Distance
40	0	1.1	40.02	86
40	3.2	1.1	40.14	86
40	6.4	1.1	40.52	87
40	9.6	1.1	41.15	88
40	0	5.14	40.33	86
40	3.2	5.14	40.46	86
40	6.4	5.14	40.83	87
40	9.6	5.14	41.46	89
40	0	8.49	40.89	87
40	3.2	8.49	41.02	88
40	6.4	8.49	41.39	88
40	9.6	8.49	42.00	90
40	3.2	1.1	40.14	86
40	6.4	1.1	40.52	87
40	9.6	1.1	41.15	88
40	3.2	4.45	40.37	86
40	6.4	4.45	40.75	87
40	9.6	4.45	41.38	88
40	3.2	8.49	41.02	88
40	6.4	8.49	41.39	88
40	9.6	8.49	42.00	90

The forces are calculated and applied in the form of UDL as shown in the figure 3. The table below are the Loads originating due to blast source.

Where
X,Y,Z are distance of point of interest from the blast source
P_{ro} – Peak Reflected over pressure
A – Exposed area

Table 2: P_{ro} Blast load on front face of the building

Scaled Distance	Pro (kg/cm^2)	Pro (KN/m^2)	A (m^2)	Force (KN)
86	0.52	51	2.03	104
86	0.52	51	2.03	104
87	0.5	49	2.03	100
88	0.48	47	2.00	94
86	0.52	51	3.69	188
86	0.5	49	3.69	181
87	0.5	49	3.69	181
89	0.47	46	3.75	173
87	0.5	49	1.69	83
88	0.52	51	1.69	86
88	0.48	47	1.69	79
90	0.48	47	1.69	79
86	0.52	51	1.69	86
87	0.43	42	1.69	71
88	0.46	45	1.69	76.1
86	0.5	49	3.69	181
87	0.43	42	3.69	155
88	0.46	45	3.75	169.2
88	0.46	45	2.03	92
88	0.42	41	2.03	84
90	0.48	47	2.00	94.1

4. Results and Discussions

The frequency and time-period of building after revision in design, however the natural frequency of the building obtained from analysis is 12.94Hz which is not equivalent with any of the mode shape frequency and by this we can say the building is secure from resonance effect.

Table 3: Reactions on supports in front face of building

NODE	LOAD CASE	FX	FY	FZ	MX	MY	MZ
1	3 BLAST LOAD	-333.213	-1528.6	5.812	9.961	0.225	367.461
2	3 BLAST LOAD	-503.943	-2059.31	9.24	8.091	2.736	606.129
3	3 BLAST LOAD	-400.787	-2028.82	13.035	9.492	2.32	509.156
4	3 BLAST LOAD	-284.453	-1771.24	13.462	12.578	-1.15	307.747
5	3 BLAST LOAD	-460.559	-1985.46	11.025	8.482	-1.606	547.329
6	3 BLAST LOAD	-359.328	-1577.46	7.264	6.964	-0.346	518.306

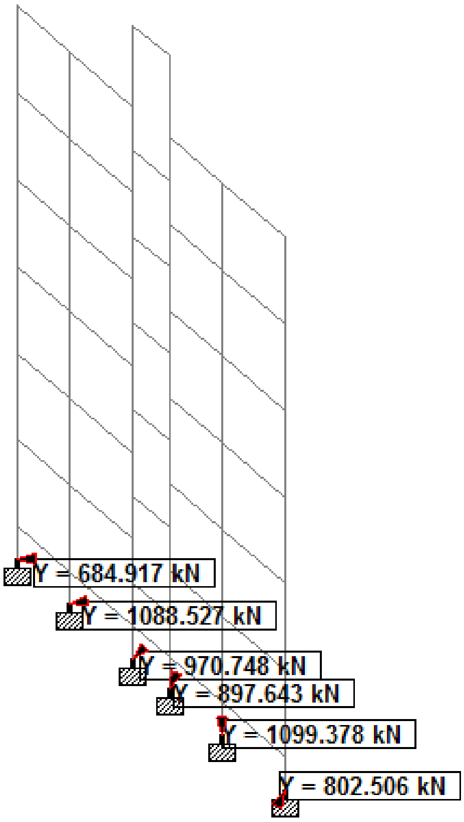


Figure 4: Support reactions on front face of building due to Factored loads

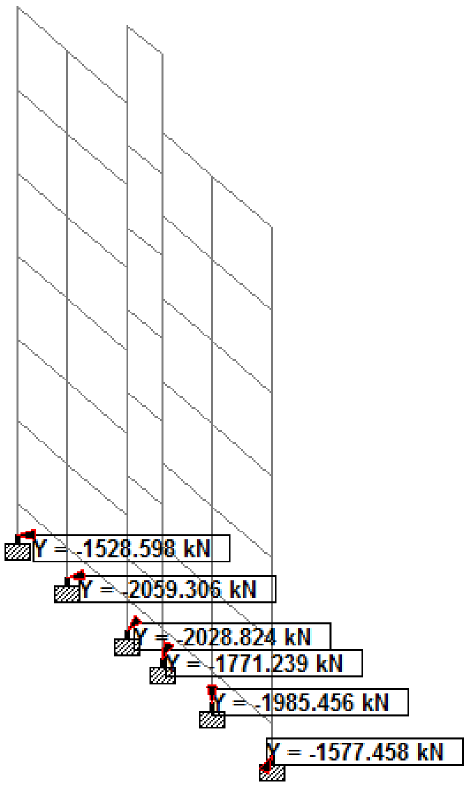


Figure 5: Support reactions on front face of building due to blast loads

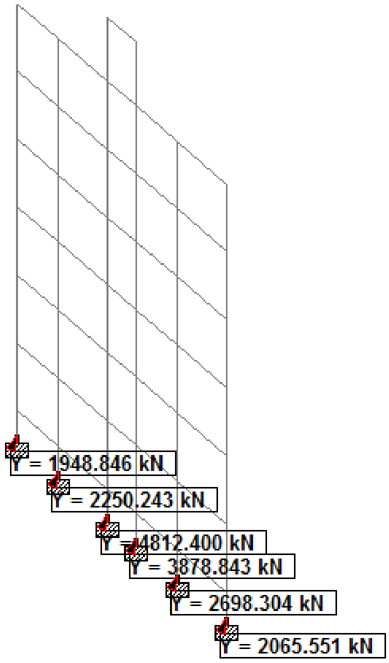
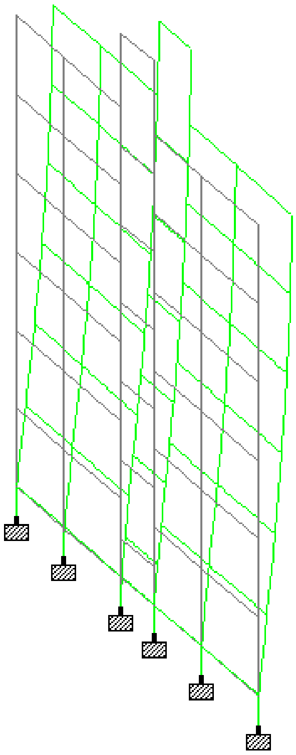


Figure 6: Support reactions at back face of building due to blast loads

It is observed that uplift force comes into picture immediately after the application of blast force and the uplift force for the proposed charge weight 100KG on the building subjected to blast force is very small when compared to dead weight of the building, so that it can resist uplift force developed by 100KG blast source, but care should be taken while designing foundation on rare side of the building because crushing force comes into picture on application of blast load which will be same as uplift force on front face due to blast force.



Load 3 : Displacement

Figure 7: Deflection diagram

Table 4: Deflections after application of blast loads

	Node	L/C	Horizontal (X)	Vertical (Y)	Horizontal (Z)	Resultant
Max X	1025	3 BLAST LOAD	1103.414	12.595	-21.449	1103.694
Min X	1	3 BLAST LOAD	0	0	0	0
Max Y	1130	3 BLAST LOAD	467.518	34.822	4.479	468.835
Min Y	1205	3 BLAST LOAD	1102.813	-24.798	23.525	1103.342
Max Z	1205	3 BLAST LOAD	1102.813	-24.798	23.525	1103.342
Min Z	1040	3 BLAST LOAD	1091.583	10.972	-21.456	1091.849
Max rX	1138	3 BLAST LOAD	467.577	25.239	4.513	468.279
Min rX	1123	3 BLAST LOAD	258.283	0.73	2.722	258.298
Max rY	1227	3 BLAST LOAD	250.192	-5.372	4.229	250.286
Min rY	1054	3 BLAST LOAD	1010.307	11.072	-21.403	1010.594
Max rZ	1130	3 BLAST LOAD	467.518	34.822	4.479	468.835
Min rZ	1042	3 BLAST LOAD	354.695	5.941	-6.903	354.812
Max Rst	1025	3 BLAST LOAD	1103.414	12.595	-21.449	1103.694

From the above table the displacements in X-direction is observed to be very huge and moreover leads to Failure of structural members

Therefore modification in design to be done in order to resist blast loads and the following modifications done in my present study in order to resist blast loads are:

Addition of RC wall on Exposed face of the building in order to Decrease intensity of blast forces and also provides additional stiffness to the frame. Bracings are added on sides of building to add stiffness to the building so that displacements are reduced

Sizes of columns and beams are increased to increase flexural rigidity of structure so that bending moments and deflections are controlled. The following figure below represents modifications in design for resisting blast loads.

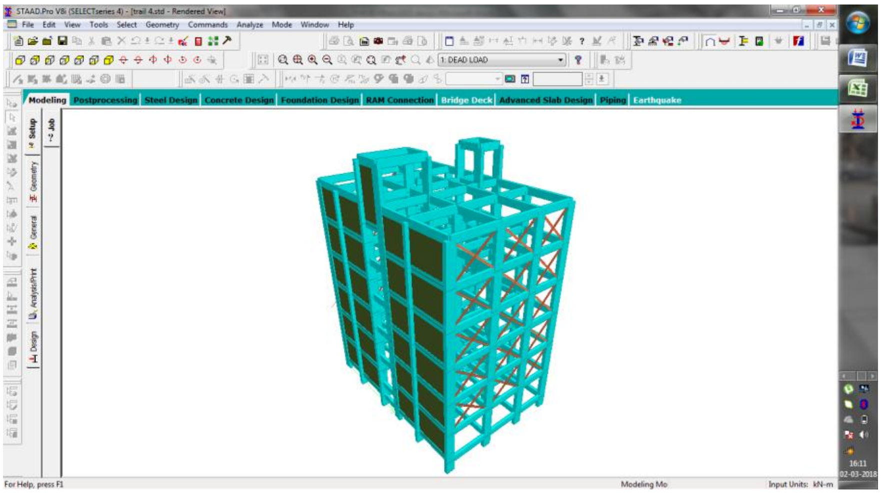


Figure 8: Modifications done in Design

Analysis is carried out and results are found to be satisfactory and all the members are passed within the allowable deflection. The deflections are obtained after analysis are tabulated below.

The maximum deflection allowable is H/150 where
H – Height of the building

Table 5: Deflection obtained after modification in design

	Node	L/C	Horizontal (X)	Vertical (Y)	Horizontal (Z)	Resultant
Max X	1215	3 BLAST LOAD	67.265	-2.733	-1.706	67.10
Min X	1	3 BLAST LOAD	0	0	0	0
Max Y	1130	3 BLAST LOAD	53.247	3.747	0.086	53.378
Min Y	1202	3 BLAST LOAD	92.429	-3.529	-0.938	92.501
Max Z	1240	3 BLAST LOAD	47.783	1.211	4.888	48.048
Min Z	1236	3 BLAST LOAD	49.743	1.216	-3.302	49.867
Max rX	1138	3 BLAST LOAD	55.344	2.535	0.074	55.402
Min rX	1238	3 BLAST LOAD	36.739	1.295	-2.424	36.842
Max rY	1007	3 BLAST LOAD	57.885	1.962	-0.097	57.919
Min rY	1061	3 BLAST LOAD	50.291	2.05	-0.68	50.337
Max rZ	1130	3 BLAST LOAD	53.247	3.747	0.086	53.378
Min rZ	1041	3 BLAST LOAD	15.897	0.663	-0.04	15.911

The deflections obtained from analysis of blast load showed satisfactory results after modification in design

5. Summary and Conclusions

In the present study a five storey R.C.C symmetric building was analyzed for blast load for 100 kg TNT placed at 40 m distance from point of explosion. Blast load is calculated from IS 4991-1968 and non-linear direct integration time history analysis is carried out on Finite element software Staad Pro. After non-linear dynamic analysis of building subjected to blast load, following conclusions were drawn.

1) Blast resistant design refers to improving structural reliability of structure instead of complete collapse of building ,The present study on S+5 Residential building prove that Increase in stiffness of structural members by increasing in size and providing bracings prove better results which also oppose the uplift force on footings by increasing in dead weights.
2) Effects of blast loads can be decreased by providing lateral moment resisting frames like shear wall thereby diminishing the effect of lateral loads which also reduce damage and increase structural integrity of the building.
3) Deviation of displacement is Non-Uniform along the height of building and unlike from earthquake and Wind (Building is not behaving as cantilever structure under blast load).
4) According to the results, structure response is very sensitive to stand-off distance, because distance between the charge and the target is one of the main parameters that characterizes blast loads. Therefore, increasing distance will diminish the structural damage under blast loads. Such measures can include either control of public access to protect building against vehicles attack.
5) For the significant structures, blast analysis needs to carry out by keeping in view the terrorist activities in today's circumstances.

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