Performance Assessment of Structure under Blast Load

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Abstract - It has become crucial to take into account blast load impacts from the stage of building a structure, similar to how you would take into account earthquake loads, wind loads, etc., due to the exponential rise in terrorist threats and actions in recent years across the globe. The primary goal of this work is to reduce the blast load effect on the structure. The blast load explosion must be given consideration during the architectural and structural design processes. More damage is done to the buildings as a result of blast loads. Hence it should be given consideration during the design process itself. Because it is not a cost-effective technology, the construction cannot be totally blast resistant. Regular buildings are not constructed to withstand explosives effects since they would be too expensive and the magnitude will be too large. The current work is related with the analysis of blast load. In this work considering a various number of charge weight varying between 100 to 400kgs at an interval of 100kgs and standoff distances varying between 15 to 25m at an interval of 5m as per IS: 4991 specification. In this research the building is analysed for blast loads by using ETABS software. The design aspects considered are Maximum joint Displacement, Number of beams and columns failed, Time Period v/s modes and Frequency v/s modes were compared after modification of structure.

Key Words – ETABS Software, Charge weight, Standoff distance, Number of beams and columns failed, Maximum joint displacement, Time Period v/s modes, Frequency v/s modes.

I. INTRODUCTION

A thorough understanding of blast characteristics will enable more competent blast resistant building design. Basic techniques for improving a structure's ability to withstand a blast should consider both the architectural and structural approach. The primary goal of the study is to offer recommendations for blast-resistant building design. ETABS software will be used to determine how a structure will respond to a blast load, with emphasis placed on a range of standoff distances between the blast and the building in addition different TNT charge weights in keeping with IS Code 4991. According to the requirements of IS 875, the Dead loads, Partition Wall loads, and Live loads are given into consideration for the evaluation of the building based on the demands and objectives of the building.

II. METHODOLOGY

1. Description of Structure

The present analysis is carried out for the models under 12 cases where in each model the value of pressure of blast load is varied according to the value obtained by varying the charge weight & the standoff distances. The modification is made to the structural elements to withstand the blast load are analysed by using ETABS software.

2. Properties of Structural Members

The building and modelling process utilized in this project is described in detail as follows:

1) Site dimensions - 16m x 14m.
2) Plan's horizontal dimension is 16m & it has 4 bays of 4 meters each.
3) Plan's vertical dimension is 14m & it has 4 bays of 3.5 meters each
4) Overall height of the building 18 meters with each floor height 3 meters & footing level is 1.5m below ground level.
5) Initial column dimensions given without blast load - 400mm x 400mm
6) Initial beam dimensions given without blast load - 300mm x 400 mm
7) Thickness of Slab - 150 mm thick
8) All the columns are assumed to be fixed at their base.
9) Characteristic strength of concrete used in beams, columns & slabs is - fck=30N/mm^2
10) Characteristic yield strength of steel used in beams, columns & slabs - fy=550 N/mm^2
11) Density of materials used. Brick - 22kN/m^3, R.C.C - 25kN/m^3

2.1 Loads Considered in Design

1) Wall load applied on beams - 2.6m x 0.23m x 22 kg/m^3=13.2kN/m.
2) Floor finish load - 1 kN/m^2
3) Live load - 5 kN/m^2

2.2 Loads Combination in Design

1) 0.9Dead Load + 1Blast Load
2) 1.2Dead Load + 1.2Blast Load + 1Blast Load
3) 1.5Dead Load + 1.5Live Load
4) 1.5Dead Load + 1Blast Load

3. Calculation of blast load according to IS 4991

One gram of TNT explosive releases 1000 calories worth of energy. Calculation of Blast Loads for various Charge weights & standoff distances are done below. Pressure- Time curve on rectangular above ground building is also plotted for each case. Total of 12 cases are considered by varying charge weight & standoff distances.

Case 1

Blast parameters obtained due to the denotation of a 0.100 tonne TNT (100kg's charge weight) explosive & standoff distance of 15m are evaluated on an above ground rectangular structure for

Height of the building: 19.5m

Length of the building: 16m

Width of the building: 14m

Stand-Off distance is varied from 15m to 25m.

a) *Characteristics of blast load*

Scaled distance x = 15/ $(0.1)^{1/3}$ =32.32m

From Table 1 assuming P_a=1 kg/cm^2 and for the scaled distance 30m, the pressures are directly obtained:

P_{so}=1.2 kg/cm^2

P_{ro}=3.6 kg/cm^2

q_o=0.47 kg/cm^2

The scaled times t_o and t_d obtained from Table 1 for scaled distance 32.32 m are multiplied by $(0.1)^{1/3}$ to get the values of the respective quantities for the actual explosion of 0.1 tonne charge.

t_o=24.49 x $(0.1)^{1/3}$ = 11.36 milliseconds

t_d=16.10 x $(0.1)^{1/3}$= 7.47 millisecs

$M = \sqrt{\frac{1 + 6Pso}{7Pa}} = \sqrt{\frac{1+ 6 \times 1.25}{7\times1}} = 1.43$ (M =Mach number)

a=344m/s (Velocity of sound in air at mean sea level)

U= shock front velocity= M x a 1.43x344=491.92 m/millisecond.

b) *Pressure on the Building*

H=19.5m, B=14m, L=16m

S=H or B/2 whichever is less= 19.5 & 14/2=7 so S=7m

$t_c = \frac{3S}{U} = \frac{3X7}{0.491} =$ 42.68 millisec

$t_t = \frac{L}{U} = \frac{16}{0.491} =$ 32.52 millisec

$t_r = \frac{4S}{U} = \frac{4X7}{0.491} =$56.91 millisec, $t_r > t_d$ So, no pressure on the back face are considered

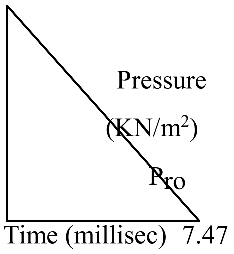
For Side face C_d= -0.4, $P_{so}+C_dq_o$ =1.4 + (-0.4) x0.471= 1.061 kg/cm^2

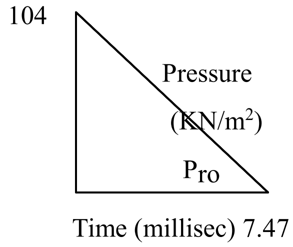
Conversion from kg/cm^2 to kN/m^2 = 1.061 x 9.81 N/cm^2 = (10.40N) /(10^{-4}m^2) = 104 kN/m^2

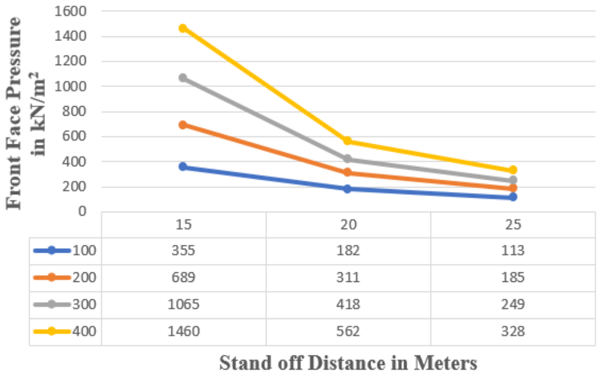
For Front face Pressure = 3.62 kg/cm^2

Conversion from kg/cm^{2}to kN/m^2 = 3.62 x 9.81 N/cm^2 = (35.51N) /(10^{-4}m^2) = 355.10 kN/m^2

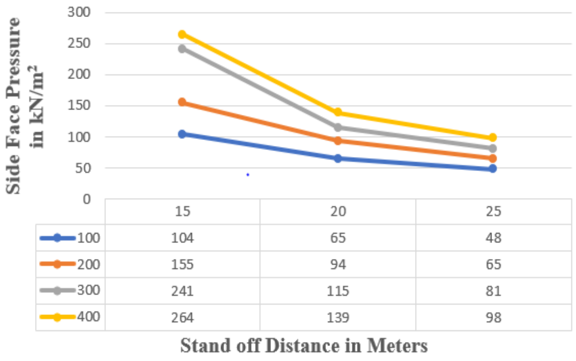
355







	15	20	25
100	355	182	113
200	689	311	185
300	1065	418	249
400	1460	562	328



	15	20	25
100	104	65	48
200	155	94	65
300	241	115	81
400	264	139	98

Graph.1 Front Face and Side Face Pressure obtained for 12 cases

3. Model in ETABS Software

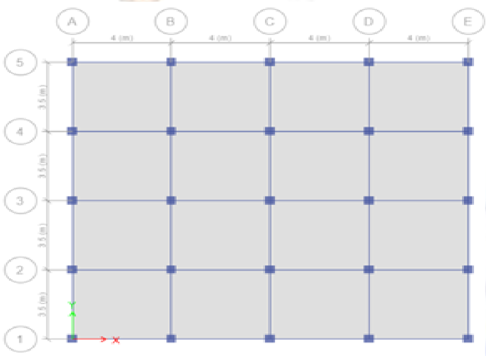


Figure 1: Plan

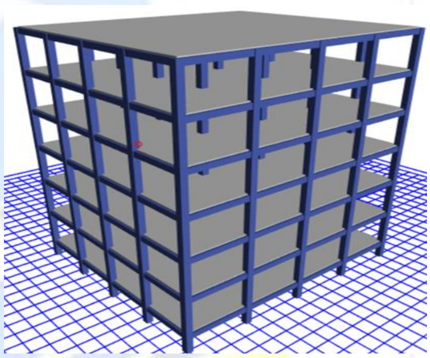


Figure 2: 3D Model

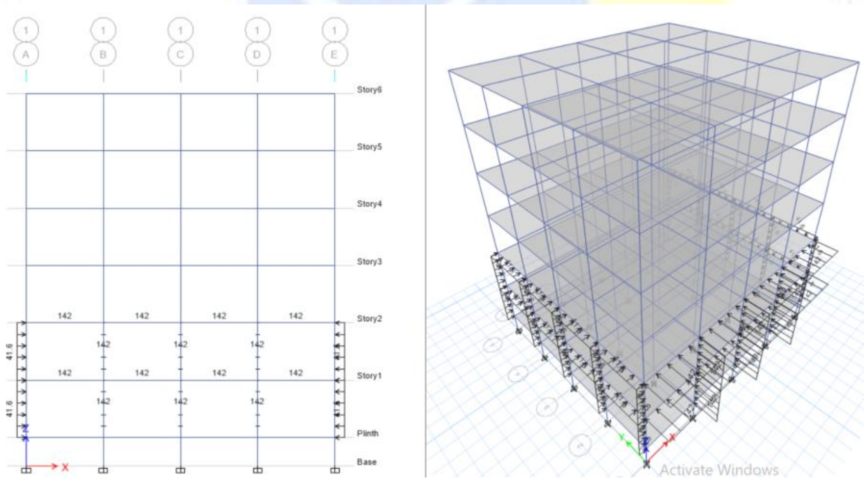


Figure 3: Blast load - Front face & Side face blast loads are calculated for 12 models and analyzed.

III. RESULTS AND DISCUSSIONS

1.Linear Static Analysis Results

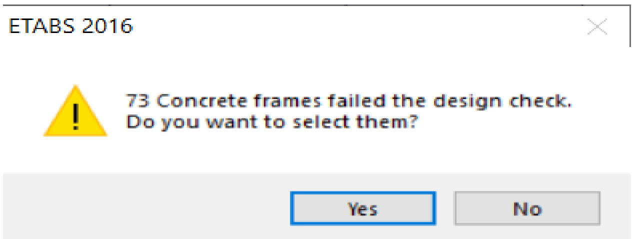


Figure 4: Number of failed beams/columns of 100 kg charge weight & 15m standoff distance without bracings

2. Modification of the Structure

A design check is performed on the structure. The number of beams and columns that are failed due to shear or flexure or torsion are selected & the cross-sectional area are enhanced by adding bracings to the structure. The beams & columns can also be strengthened by adding bracings (ISA 150X75X8mm) to the structure. After the modifications of the structure by adding bracings they are analysed & again verified whether it can with stand the loads imposed on it.

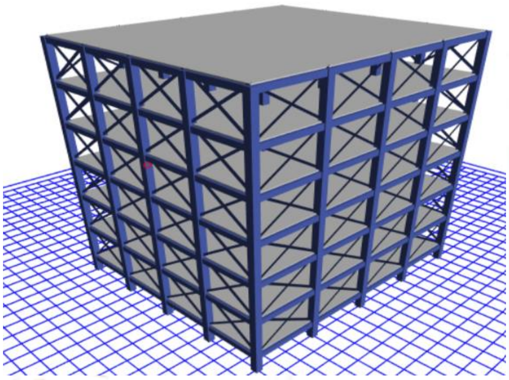


Figure 5: Modification of the Structure.

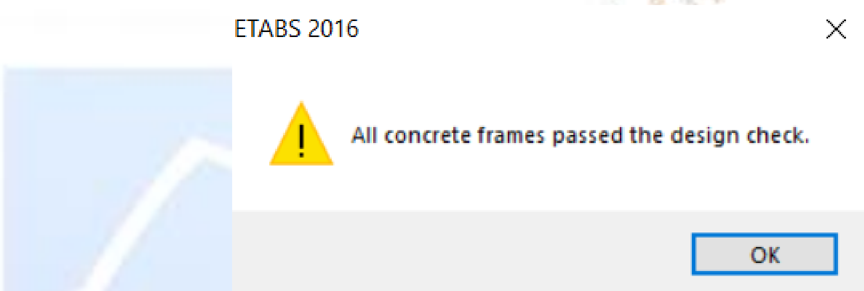
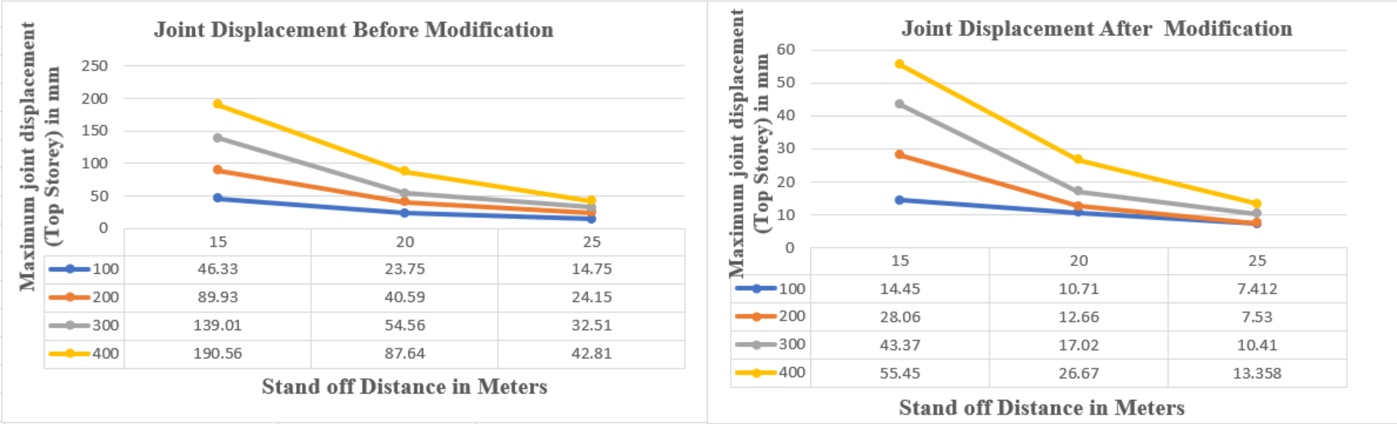


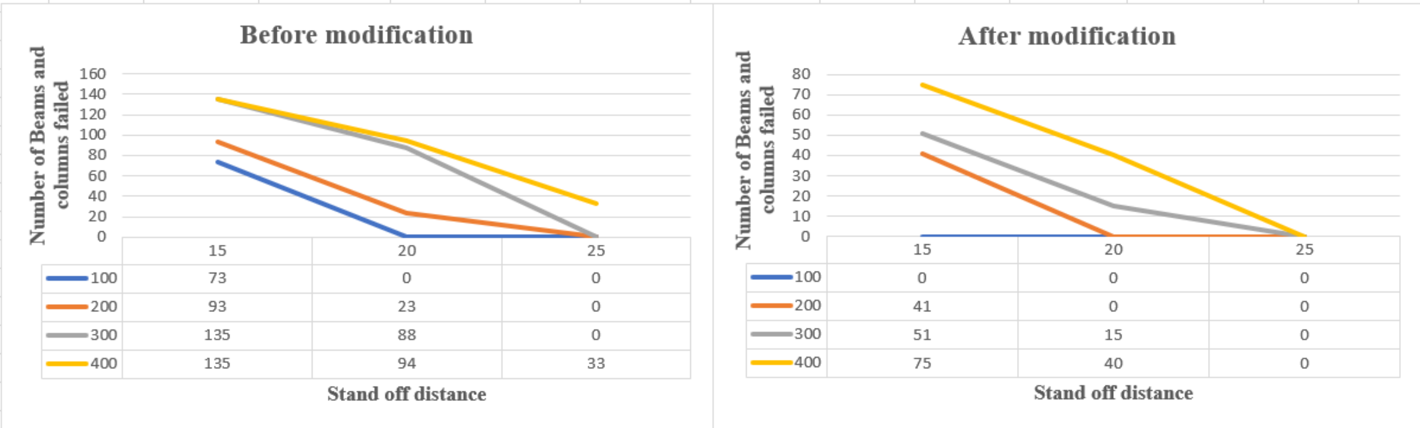
Figure 6: All Column and Beams passed the design after modification

Table 1: Details of the results

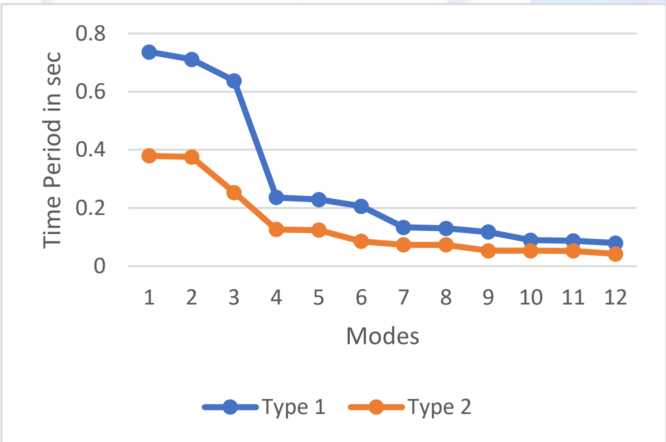
Case No	Denotation Charge Weight (TNT in Kgs)	Stand Off Distance (m)	Front face Pressure developed by Blast (KN/m^2)	Side face Pressure developed by Blast (KN/m^2)	Maximum Joint Displacement (Top Story) in mm		No of beams or columns failed	
					Without bracings	With bracings	Without bracings	With bracings
1	100	15	355	104	46.335	14.458	73	0
2	100	20	182	65	23.755	10.715	0	0
3	100	25	113	48	14.749	7.412	0	0
4	200	15	689	115	89.93	28.06	93	41
5	200	20	311	94	40.592	12.66	23	0
6	200	25	185	65	24.14	7.534	0	0
7	300	15	1065	241	139.00	43.373	135	51
8	300	20	418	115	54.558	17.023	88	15
9	300	25	249	81	32.51	10.141	0	0
10	400	15	1460	264	190.56	55.459	135	75
11	400	20	562	139	87.643	26.675	94	40
12	400	25	328	98	42.811	13.358	33	0



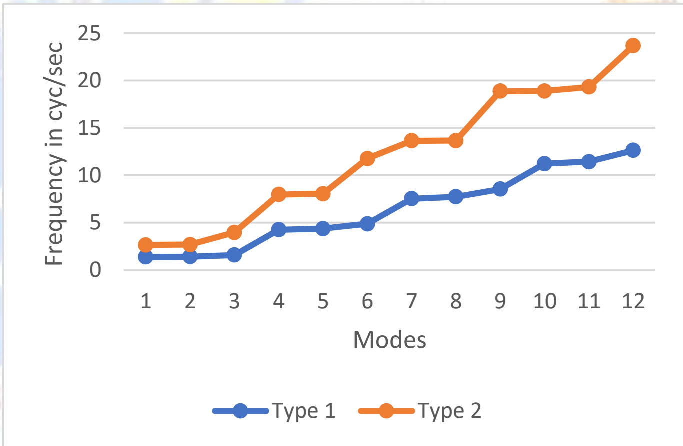
Graph 2: Joint Displacement plotted before and after modification



Graph 3: Number of Beams columns failed before and after modification



Graph 4: Time Period v/s Mode



Graph 5: Frequency v/s Mode

IV. CONCLUSIONS

From the Linear Static Analysis results it can be shown that, the Displacement is smaller in modified model because of bracings, the number of failed structural elements decreases after modification and the period decreases with increase in number of modes and the frequency of the structure increases with increase in number of modes. The modified modified structure shows large values of frequency because of bracings.

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