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Evaluation of Standoff Distance and Explosion Weight for a Blast Resistant Structure

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Abstract: Manmade vibrations are most affected on the buildings due to the huge amount of external pressure. These vibrations are acted on the building which are near quarries due to the explosion of rock, due to the hydraulic drilling of the rock, heavy vehicular traffic etc. Among all the buildings which are nearer to quarries are most effected to vibration. In this study work is carried out to analyse the performance of the building for manmade vibrations caused by explosion of rock nearby construction site. In this regard a RCC building of size 18m x18m and modelled in ETABS13 for the analysis, it has been suggested the safe stand-off distance and safe explosion charge weight for the stability of the structure. The results obtained clearly mentions that for a building to be stable for blast load created by minor explosions at construction site, amount of charge weight should not be more than the specified weight respective to the specified stand-off distance.
Keywords: Blast waves, Standoff distance, Charge weight

I. INTRODUCTION

As we are living in a worlds second populated country, as population increases the development of the residential areas also goes on expanding and these residential areas are merging into industrial areas, lakes, quarry's and many more. Due to the explosions of the natural rock topography in the quarries the residential buildings which are present in the vicinity of quarry gets affected. It is essential to estimate and predict the effects of explosions and provide designs to protect structures against the potential explosive events. Blast loading and its effects on a structure is influenced by a number of factors including charge weight, location of the blast (or standoff distance) and the geometrical configuration and orientation of the structure (or direction of the blast) *[6]*. Blast wave is an area of pressure escalating supersonically outward from the centre of explosion. It consists of leading shock front of compressed gases and it is followed by blast wind of negative pressure, which draws items back towards the centre *[14]*. Based on the confinement of explosives blast loads are categorized into two types they are Unconfined Explosion and Confined Explosion *[5]*. Unconfined explosion has three types, Free air blast, Air blast and Surface blast. In this study we have considered Surface blast explosion. In Surface blast the explosion appears on the ground surface and due to this waves are formed initially which interact with the ground and later they spread above the ground surface in the form of hemispherical waves as shown in the fig 1.1

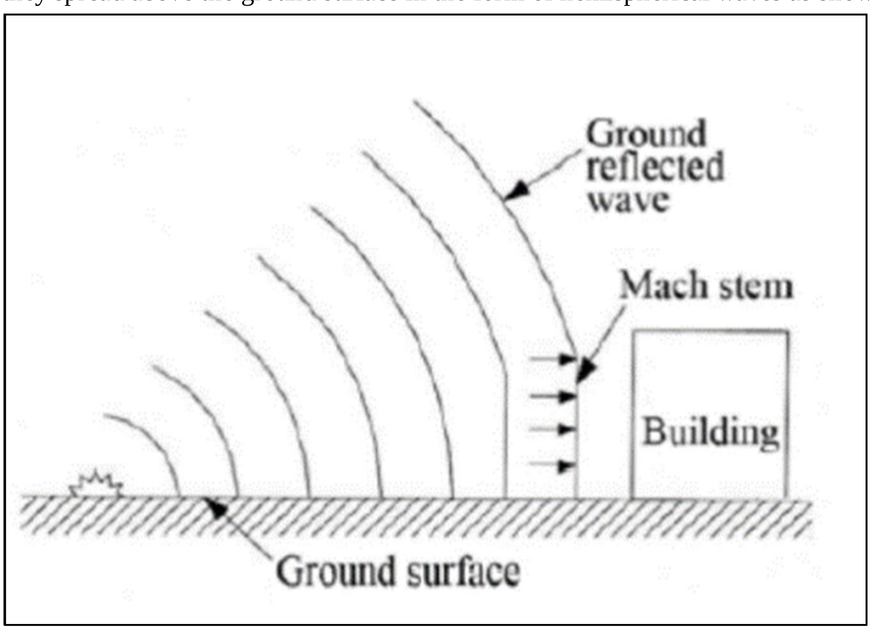


Fig 1.1 Surface blast *[14]*

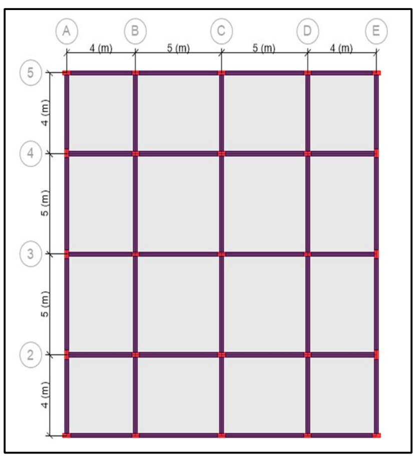
II. LITERATURE REVIEW

It was observed that the effect of blast on building depends mainly on two factors i.e. charge weight and standoff distance. Blast pressure and blast scaled distance is inversely proportional [13]. Structural elements exposed to distant explosions, conventional reinforcements provides sufficient ductility, while for close explosions additional reinforcement is required. Effect of blast load can also be reduced by providing lateral moment resisting frames like shear wall and by increase in the size of the member and their increase the stiffness which helps for the uplift of force on footings. By applying progressive collapse method and by alternate path analysis for the weaker points and replacing a conventional to a plastic hinge in the analysis which reduce the failure [14]. Comparative study of seismic load and blast load reveals that material requirement for blast resistant structure is more than 40% for concrete [1]. It is also evident that circular column can withstand more than the rectangular or square column [15]. Ultra High Performance concrete can withstand the loading more than 70% then conventional concrete with a standoff distance of 1.5m [11]. Comparative study between spatial and non-spatial analyses, reveals that structural response is lower and the probability of damage is 5–200% higher in spatial analyses [16].

III. METHODOLOGY

In this study, G+2 storey RCC bare frame subjected to surface blast of having a plan dimension of 18m X 18m with x and y direction of each 4 bays were considered. The corner bays are of size 4m x 4m, except corners the peripheral bays are of size 4m x 5m and the intermediate bays are of size 5m x 5m, and remaining all storey heights as 3m each. The building is analysed for different standoff distance of 9.14 m, 15.24 m and 30.48 m from the front face of the building using ETABS2013. The blast load parameters are computed as per IS: 4991-1968. The blast load is multiplied with its tributary area and these pressures are applied as a joint load on the front face of the building. The safe standoff distance and safe explosion charge weight is evaluated and calculated by trial and error method.

IV. MODELLING AND ANALYSIS



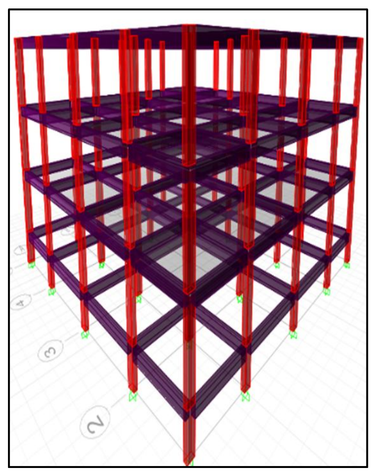


Fig 4.1 Plan and 3-D model of the bare frame building

In this study the material properties used are concrete grade M25, rebar grade Fe500, density of concrete 25 kN/m^3 , density of steel 78.5 kN/m^3, column of size 230mmx450mm, beam of size 230mmx450mm and slab of thick 150mm. General loading on the structures is considered as per IS 875:2016 (Part- 1) and (Part-2)

A. Blast Analysis

The analysis of G+2 storey building with a varying standoff distance as 9.14 m, 15.24 m and 30.48 m are done using ETABS 2013. By trial and error method a safe explosion charge weight is found out as per IS: 4991: 1968. The blast pressure calculated due to explosion occurring at different standoff distance and different charge weight are tabulated below. The pressure is multiplied with the tributary area and then applied to the joints is shown in the fig 4.2

'Z' indicates distance between source and target in meters

'P' indicates peak reflected over pressure in kN/m^2

'F' Joint load (nodal force) in kN.

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TABLE 4.1 Calculation OF Blast Parameters For Charge Weight OF 0.45 KG and Standoff Distance 9.14 M

Joint	Level	Z in m	Scaled Distance in x in m	Peak reflected over pressure in kN/m^2	Area in m^2	Force in kN
1	Ground Floor	9.26	116.7	34.101	11.25	384
2 & 4		10.53	132.6	28.795	10.13	292
3 & 5		12.91	162.7	18.762	4.50	84
1	First Floor	10.19	128.4	30.214	15.00	453
2 & 4		11.35	143.0	25.339	13.50	342
3 & 5		13.59	171.3	15.910	6.00	95
1	Second Floor	11.82	149.0	23.345	15.00	350
2 & 4		12.84	161.7	19.088	13.50	258
3 & 5		14.86	187.2	10.596	6.00	64
1	Terrace	13.92	175.4	14.536	15.00	218
2 & 4		14.79	186.4	10.879	13.50	147
3 & 5		16.58	208.9	7.33	6.00	44

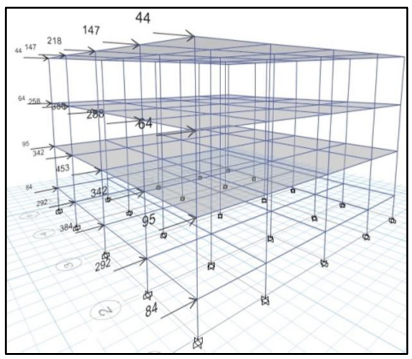

Fig 4.2 Blast load applied at joints for the Standoff distance 9.14 m

The blast pressure calculated due to explosion occurring at distance of 15.24 m and charge weight of 1.05 kg are tabulated below.

Table 4.2: Calculation Of Blast Parameters For Charge Weight Of 1.05 Kg And Standoff Distance 15.24 M

Joint	Level	Z in m	Scaled Distance in x in m	Peak reflected over pressure in kN/m^2	Area in m^2	Force in kN
1	Ground Floor	15.31	150.7	22.778	11.25	256
2 & 4		16.11	158.5	20.169	10.13	204
3 & 5		17.76	174.8	14.747	4.50	66
1	First Floor	15.89	156.3	20.886	15.00	313
2 & 4		16.66	163.9	18.367	13.50	248
3 & 5		18.26	179.7	13.108	6.00	79
1	Second Floor	16.99	167.1	17.295	15.00	259
2 & 4		17.71	174.2	14.932	13.50	202
3 & 5		19.22	189.1	9.958	6.00	60
1	Terrace	18.51	182.1	12.305	15.00	185
2 & 4		19.17	188.6	10.129	13.50	137
3 & 5		20.58	202.5	18.8	6.00	113

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The blast pressure calculated due to explosion occurring at distance of 30.48 m and charge weight of 6.5 kg are tabulated below.

Table 4.3: Calculation Of Blast Parameters For Charge Weight Of 6.5 Kg And Standoff Distance 30.48 M

Joint	Level	Z in m	Scaled Distance in x in m	Peak reflected over pressure in kN/m^2	Area in m^2	Force in kN
1	Ground Floor	30.52	163.5	18.494	11.25	208
2 & 4		30.92	165.7	17.767	10.13	180
3 & 5		31.82	170.5	16.173	4.50	73
1	First Floor	30.81	165.1	17.969	15.00	270
2 & 4		31.21	167.3	17.249	13.50	233
3 & 5		32.10	172.0	15.670	6.00	94
1	Second Floor	31.39	168.2	16.936	15.00	254
2 & 4		31.78	170.3	16.229	13.50	219
3 & 5		32.65	175.0	14.677	6.00	88
1	Terrace	32.24	172.7	15.420	15.00	231
2 & 4		32.62	174.8	14.731	13.50	199
3 & 5		33.47	179.3	13.218	6.00	79

V. RESULTS AND DISCUSSION

The behaviour of building when subjected to blast placed perpendicular to the front face of the building with a blast source of varying weight and at different standoff distance is analysed and the response quantity of buildings such as storey displacement, storey drifts is obtained from ETABS 2013. The results are extracted and tabulated in the table 5.1 and table 5.2.

A. Storey Displacement

The displacement of the building when exposed to surface blast load of 0.45 kg, 1.05 kg and 6.5 kg at various standoff distance of 9.14 m, 15.24 m and 30.48 m from front face of the building are extracted and tabulated in table 5.1

Table 5.1: Displacement (MM) of the Building for Various Charge Weight and Standoff Distance.

Level	Displacement for Standoff Distance 9.14 m in mm	Displacement For Standoff Distance 15.24 m in mm	Displacement For Standoff Distance 30.48 m in mm	Max Lateral displacement as per IS 1893:2016 in mm
Terrace	40.2	35.6	38.7	42
Second floor	34.6	29.8	32.1	
First Floor	22.2	18.5	19.6	
Ground Floor	3.9	3.2	3.4	
Basement	0	0	0	0

The displacement of the building when subjected to a blast load at various Standoff distance with varying charge weight of explosive is shown in the table 5.1. It is observed that the displacement increases when the source of explosion is nearer to the building and it decreases with increase in standoff distance. We can observe that the lateral displacement in permissible limits as per IS 1893:2016 *[7]*.

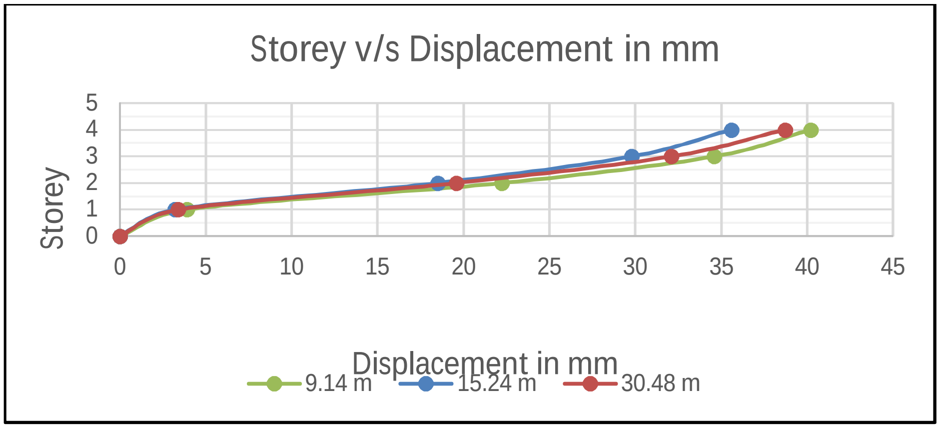

Fig 5.1 Comparison between storey and displacement in mm

B. Storey drift

The displacement of the building when exposed to surface blast load of 0.45 kg, 1.05 kg and 6.5 kg at various standoff distance of 9.14 m, 15.24 m and 30.48 m from front face of the building are extracted and tabulated in table 5.2

Table 5.2: storey drift in 10^{-3} of the building for various charge weight and standoff distance.

Level	Displacement For Standoff Distance 9.14 m in mm	Displacement For Standoff Distance 15.24 m in mm	Displacement For Standoff Distance 30.48 m in mm	Max Lateral displacement as per IS 1893:2016 in mm
Terrace	0.001846	0.001927	0.002174	0.012
Second floor	0.004144	0.003759	0.004169	0.012
First Floor	0.006151	0.005149	0.005458	0.012
Ground Floor	0.003516	0.002716	0.002665	0.012
Basement	0	0	0	0

In table 5.2, the storey drift of building when subjected to a blast placed at different standoff distance is tabulated. It is observed that drift increases when blast is closer to the building, while it is less as the blast source is far away from the building. Thus, it is observed that drift is inversely proportional to stand off distance i.e., drift increases with decrease in standoff distance and directly proportional to charge weight i.e., drift increases with increase in charge weight and vice versa. It is also observed that drift is higher in lower storey when compared to upper storey because blast source is nearer to the lower storey. Fig 5.2 shows the graph of drift along the height of the building for various charge weight of explosion and different location of source of blast. We can observe that the storey drifts are in permissible limits as per IS 1893:2016*[7]*.

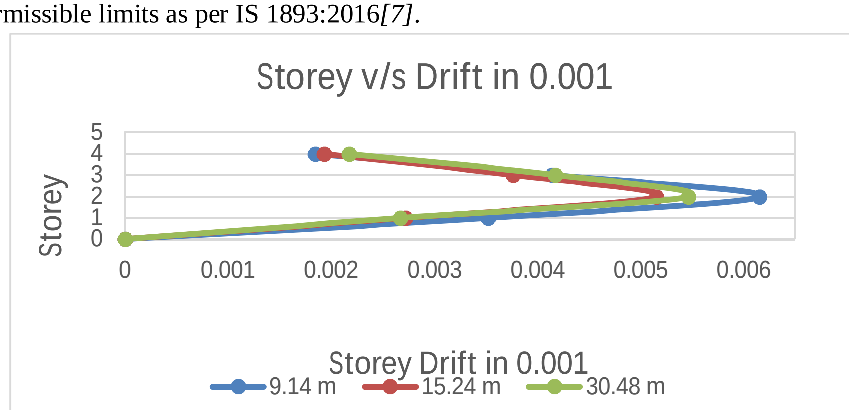

Fig 5.2 Comparison between storey and drift in 10^{-3}

VI. CONCLUSION

Joint load applied at the joints of the structure is dependent on the standoff distance, explosion weight and area of dead load presence due to the storey height and the spans of the structural elements. The safe charge weight of explosion for respective standoff distance i.e. 9.14 m, 15.24 m and 30.48 m are 0.45kg, 1.05kg and 6.5kg. Maximum lateral displacement is observed at the terrace level but the lateral displacement is less than H/250 as per IS1893:2016. Maximum storey drift is observed at the first floor level but the storey drift is less than 0.004H as per IS1893:2016. A building which has to resist a blast load then the explosion amount of charge weight should not be more than the above specified weight respective to the specified stand-off distance.

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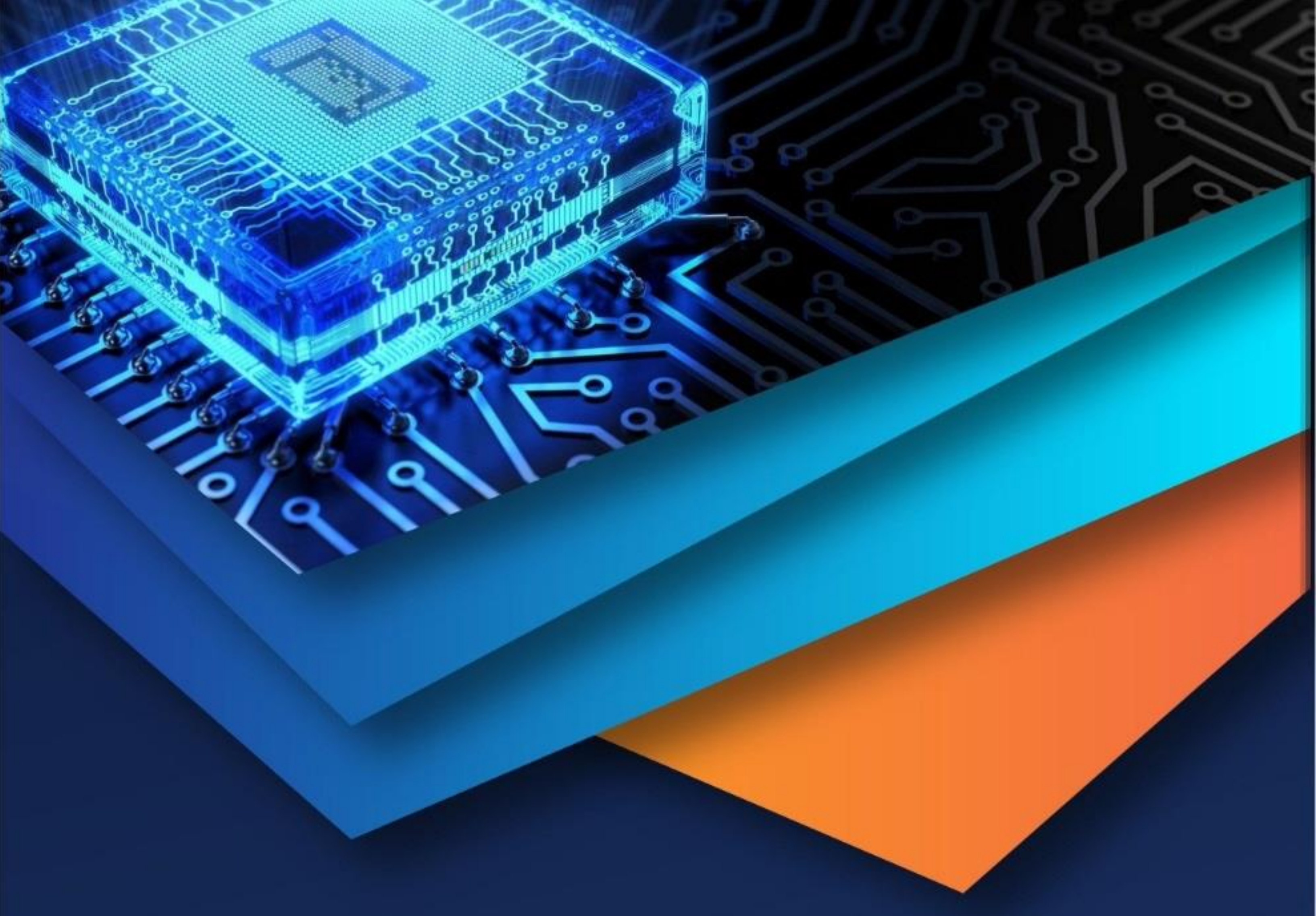

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