BEHAVIOR OF FLAT SLAB STRUCTURES SUBJECTED TO SURFACE BLAST LOADS

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Abstract – *The role of structural engineer is to design the structures for the safety and providing good shelter. From past few decades the accidental explosion activities are increasing due to which the structures are failing to withstand blast loads. Researchers have analyzed for safe possible distances of blast loads on low rise structures. In this thesis, structure with G+5, G+7 and G+10 storey flat slab structures is subjected to HMX charge weight with varying stand-off distances. Linear static analysis is performed suing ETABS tool. The response of flat slab structures is determined in terms of storey drifts, storey displacement, axial loads, bending moment and lateral loads. Storey drift was greater in third floor for G+5 and G+7 flat slab structure and fourth floor for G+10 flat slab structures. Detonation point increases as pressure varies inversely with stand-off distance. Storey displacement decreases polynomial with increase with of stand-off distance. Lateral loads increases polynomial with increase in storey heights.*

Key Words: Accidental explosions, HMX charge weights, stand-off distance, Etabs 2016

1. INTRODUCTION

In last decades, the increasing threat of terrorism activities have shown the impact of blast loads on structures and this resulted in collapse of structures and loss of life. The magnitude of blast loads is high and when these blast loads are applied on structure they fail to withstand hence, structures should be designed for design loads along with low construction cost.

The terrorist attack on the building such as, World Trade Centre situated in New York (1993), Murrah Federal building situated in Oklahoma City (1995) and U.S embassies located in Nairobi (1998) were subjected to blast or impact loadings. These structures have failed to save the life of the people and structural disasters. Hence, guidelines principles are made in metropolitan cities to construct the structures within safe permissible limits. The progressive collapse of the buildings which are triggered by blast loads have been endorsed to failing of the joints between beams and columns and beams and slabs.

2. EXPLOSION AND BLAST WAVE

An explosion is an instantaneous chemical reaction which occurs with the production of hot gases and energy. The explosion results in very milliseconds with release of high temperature and pressures. The hot gases which are emitted when blast is taken place, they travel in surrounding medium in the form of waves, either in the form of spherically or hemi spherical through medium. The released hot gases causes the surrounding air to get expand and number of molecules in air rises up and resulting in the form of blast wave. Blast wave velocities are higher than the velocity of sound waves.
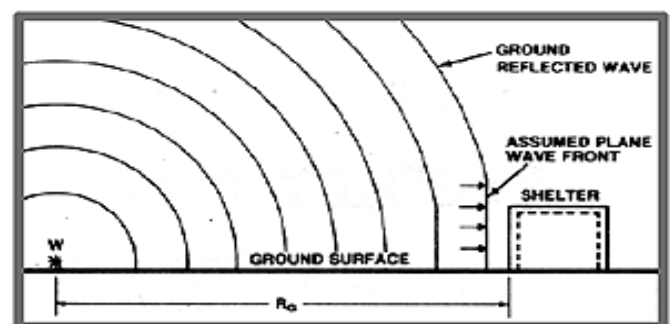

Figure-1: Blast Wave Propagation.

3. TYPES OF BLAST LOADS

Blast loads are categorised into two main confinements of explosives as

1. Unconfined Explosions.

2. Confined Explosions.

3.1 Unconfined Explosions

The explosions occurring in an open medium is known as unconfined explosion. This type of explosion produces waves from the point of explosion source to the structures without

change in amplitude of the blast wave. Explosions take place from the specified detonation point at the provided height away from the structures.

Unconfined Explosion is further classified into three types:
A) Free Air Blast
b) Air Blast
c) Surface Blast

In this thesis work is limited to surface blast loads only. Here the dynamic blasts loads are subjected to structures and it is known that structures are not completely protected to explosions. However, structure is designed to resist the explosion at particular stand-off distances as the hot gases are imparted a wave pressure is generated in the medium. The absolute overpressure at shock front is called as peak Overpressure. The overpressure reduces to one-half the peak overpressure and persists at the central zone of explosion. The phase at which the pressure due to explosion is higher than the atmospheric pressure is called as positive phase. As the stand-off distance increases, the effect of overpressure decreases uniformly and the velocity of the sound in the medium also decreases and at certain time the values of overpressure reduces less than the medium and hence this stage of phase is known as Negative phase.
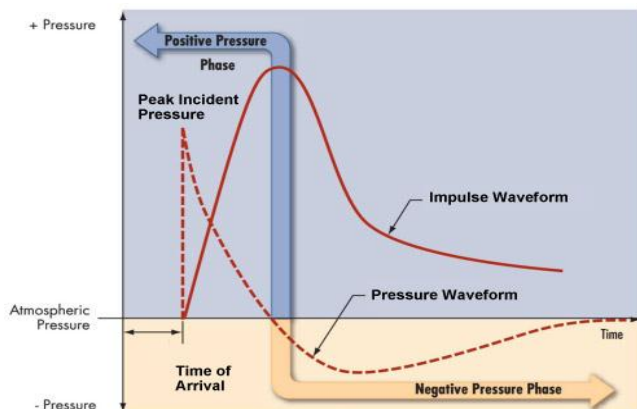

Figure-2: Variation of Overpressure

4. FLAT-SLABS

The flat-slabs is defined as, concrete slabs supported directly by concrete columns without use of beams. The different types of flat-slabs are as follows:-

a) Flat slab.
b) Flat slab with drop panels.
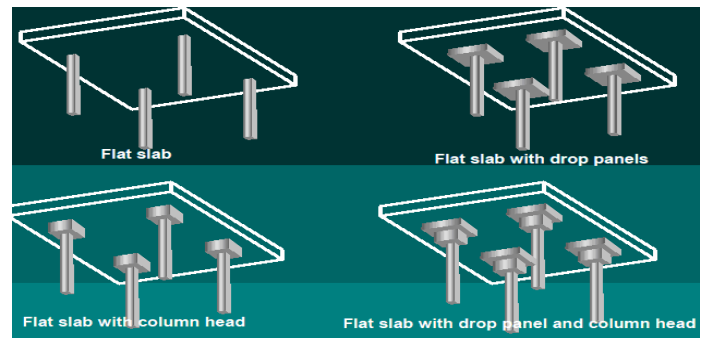c) Flat slab with column heads.
d) Flat-slab without drop panels.

Figure-3: Different types of flat-slabs

4. METHODOLOGY

Earlier several researchers worked on the structures with beam column connections. The effect of blast load on flat-slab are studied y very few researchers. Hence, in this work flat-slab were considered. The present task deals with modeling and analysis of (G+5), (G+7), (G+10) flat-slab structure subjected to 100kg of HMX explosives with different stand-off distances using ETABS 2016. The pre-determined blast loads are assigned as static joint loads in the flat-slab structure and linear static analysis is carried out for flat-slab structures.

Initially, the structures are modeled and analyzed for the assigned blast loads in ETABS tool and the structures are made safe for different materials properties and section properties. The flat-slab structures are analyzed for seismic analysis and time-history analysis firstly. Then, blast analysis is carried out for different cases and stand-off distances which are determined. Then the response of the building analyzed in ETAB tool for storey drifts, storey shears, and displacements etc.

4.1 Model Description

Plan	: 20m x 15m
X-direction	: 4 bays at 5m
Y-direction	: 3 bays at 5m
Height of each storey	: 3.5m

4.2 Properties of materials

Grade of concrete	: M30
Grade of rebar	: Fe415
Density of concrete	: 25kN/m^3
Density of Steel	: 78.5kN/m^3

Poisson's ratio   : 0.2

4.3 Sectional Properties

Column   : 600mm X 450mm

Beam (applicable for ground floor)   : 450mm X 450mm

Slab   : 200mm

Drop   : 150mm

4.4 General Loadings

Live load [IS 875, part2]   : 3kN/m^2 (Floor)

Floor Finish   : 1kN/m^2

Wall load   : 16.2kN/m

Parapet Wall load   : 3.0kN/m

Figure-4: Plan view of (G+5), (G+7), (G+10) Flat- Slab Structure.

5. BLAST LOAD CALCULATIONS

In this thesis the structure is analyzed for (G+5), (G+7) and (G+10) flat-slab subjected to 100 kg HMX explosive charge weight. The detonations are located at 10, 20, 40, 60 and 80m respectively. The blast loads are calculated according to UFC-3-340-02 (2008) and they are assigned on front face of the building and calculated loads are applied in Y-direction. The various parameters of blast wave are obtained from the chart shown in figures.

$W = W_{exp} \times [H_{exp}/H_{TNT}]$

Where,

H_{exp} = specific energy of explosive taken (HMX explosive)
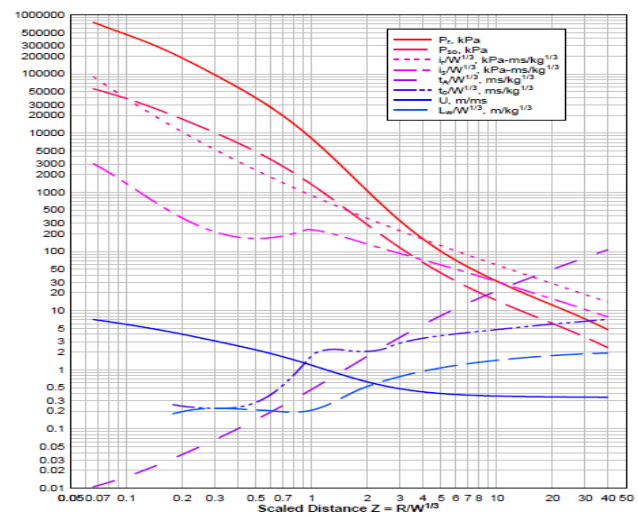
H_{TNT} = specific energy of TNT explosive

$W = 100 \times [5680/4520]$

$W = 125.6$ kg of TNT

When stand-off distance R=10m

Distance from blast load (R_h) is calculated by

$R_h = (R^2 + h^2)^{1/2}$

$R_h = (10^2 + 10.5^2) = 14.5m$

Scaled distance, $Z = [R_h/W^{0.33}]$

$Z = [14.5/ 125.66^{0.33}] = 2.89$ [m/kg$^{0.33}$]

Figure-5: Positive phase parameters at surface blast for TNT charges
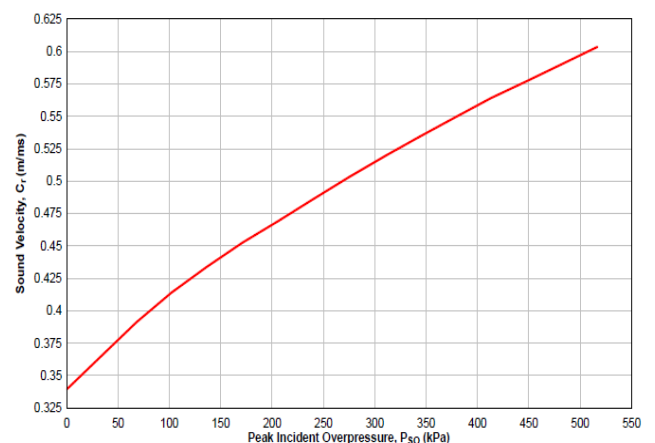

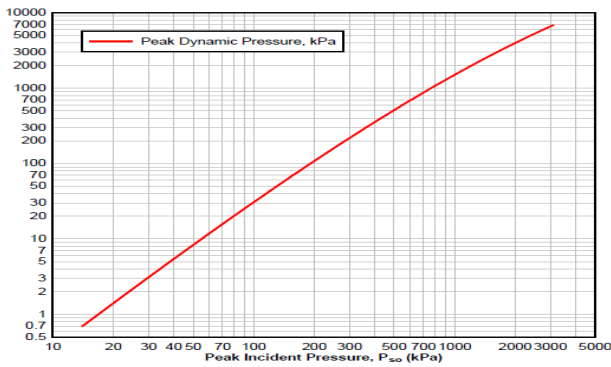**Figure-6:** Graph between sound velocity v/s overpressure

Figure-7: Graph between peak dynamic pressure (q_0) v/s incident pressures (p_{so})

Table-1: Positive phase parameter for R=10m

Front face of the building	Incident pressure P_{so} (kN/m²)	Incident Impulse i_s	Reflected Pressure P_r (kN/m²)	Reflected Impulse i_r	Arrival Time t_a (ms)	Positive Duration t_0 (ms)
Graph Read Values	160	100	400	250	3	2.9
Absolute values	160	500	400	1300	5	14.5

Pressure on front wall = [P_{so} + C_D x q_0]

$$= [160 + (1 \times 60)]$$

$$= 220 \text{ kN/m}^2$$

The blast loads parameters and pressure acting on front face of the building are calculated for [(G+5), (G+7) and (G+10)] flat-slab structure for different stand-off distance (10m, 20m, 40m, 60m and 80m). The variation of blast pressure is calculated and the calculated blast pressure is applied on front face of the structure in X-direction and results are tabulated and shown in the table.

Table-2: Blast load acting on front face of the building for (G+5) flat-slab structure

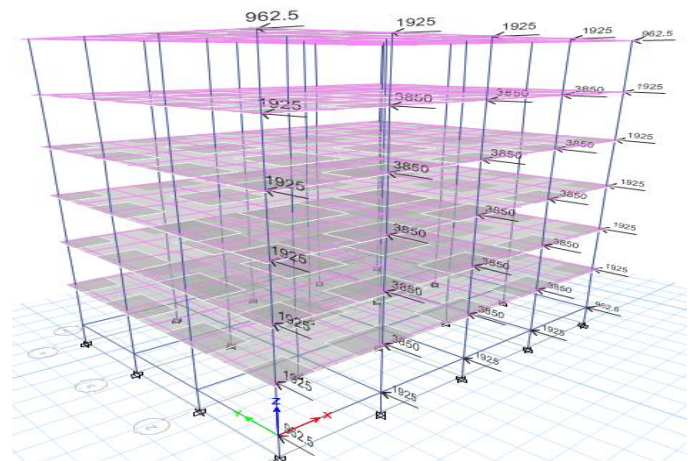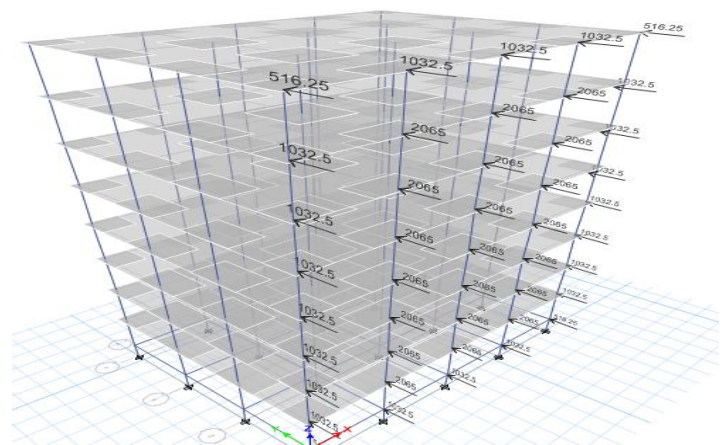| Stand-off Distance (m)	Pressure on front face wall (kN/m²)	Joint 1		Joint 2		Joint 3		Joint 4		Joint 5	
		Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)
10	220	4.375	962.5	8.75	1925	8.75	1925	8.75	1925	17.5	3850
20	59	4.375	258.1	8.75	516.2	8.75	516.25	8.75	516.25	17.5	1032.5
40	21.8	4.375	95.37	8.75	190.7	8.75	190.75	8.75	190.75	17.5	381.5
60	14.32	4.375	62.65	8.75	125.3	8.75	125.3	8.75	125.3	17.5	250.6
80	10.5	4.375	45.93	8.75	91.87	8.75	91.87	8.75	91.87	17.5	1837.5

Figure-8: Blast loads on frontal face of (G+5) flat-slab structure for the case of stand-off distance at10m

Table-3: Blast load acting on front face of the building for (G+7) flat-slab structure

Stand-off Distance (m)	Pressure on front face wall (kN/m²)	Joint 1		Joint 2		Joint 3		Joint 4		Joint 5	
		Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)
10	118	4.375	516.25	8.75	1032.5	8.75	1032.5	8.75	1032.5	17.5	2065
20	58	4.375	253.7	8.75	507.5	8.75	507.5	8.75	507.5	17.5	1015
40	19	4.375	83.12	8.75	166.25	8.75	166.25	8.75	166.25	17.5	332.5
60	15	4.375	65.62	8.75	131.25	8.75	131.25	8.75	131.25	17.5	262.5
80	80	4.375	4.37	8.75	78.75	8.75	78.75	8.75	78.75	17.5	157.5

Figure-9: Blast loads on frontal face of (G+7) flat-slab structure for the case of stand-off distance at10m

Table-4: Blast load acting on front face of the building for (G+10) flat-slab structure

Stand-off Distance (m)	Pressure on front face wall (kN/m²)	Joint 1		Joint 2		Joint 3		Joint 4		Joint 5	
		Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)	Area (m²)	Load (kN)
10	68	4.375	297.5	8.75	595	8.75	595	8.75	595	17.5	1190
20	46	4.375	201.2	8.75	402.5	8.75	402.5	8.75	402.5	17.5	805
40	20.5	4.375	89.8	8.75	179.3	8.75	179.3	8.75	179.3	17.5	358.7
60	14.8	4.375	64.7	8.75	129.5	8.75	129.5	8.75	129.5	17.5	259
80	9.4	4.375	41.1	8.75	82.25	8.75	82.25	8.75	82.25	17.5	164.5
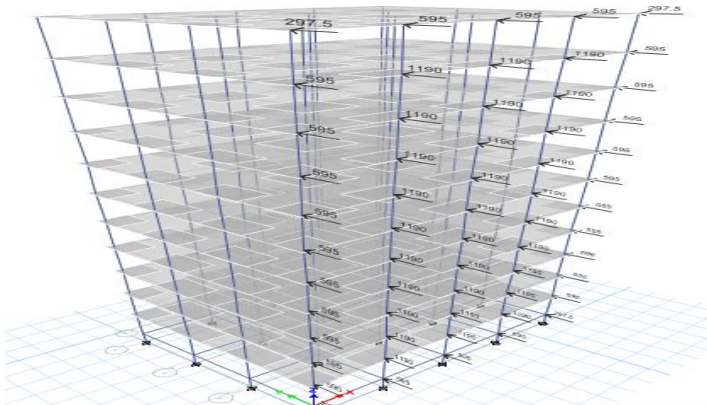
Figure-10: Blast loads on frontal face of (G+10) flat-slab structure for the case of stand-off distance at 10m

6. REULTS AND DISCUSSIONS
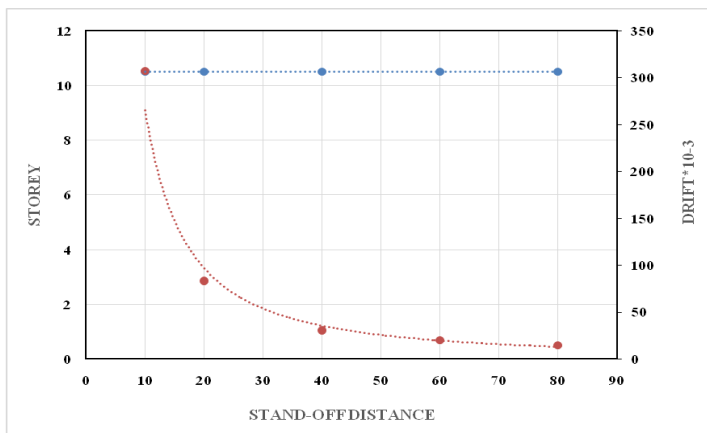
Figure-11: Variation of Storey Drifts of (G+5) flat-slab structure
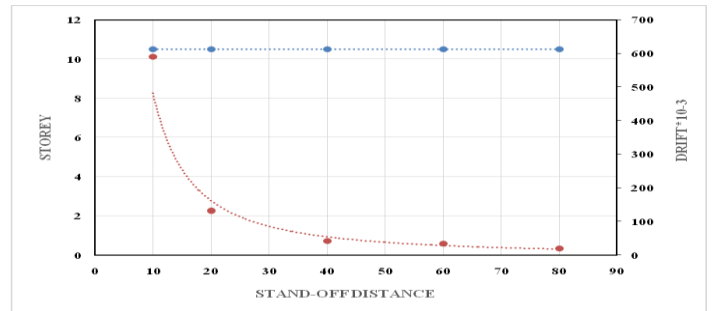
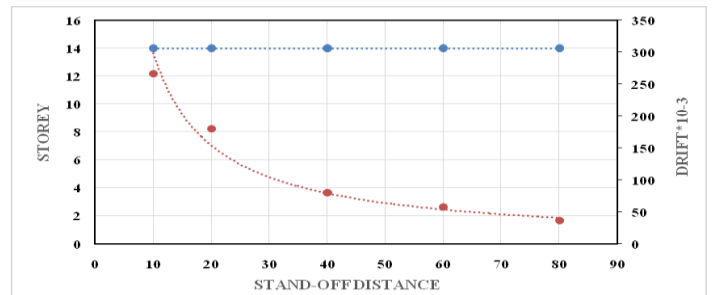**Figure-12:** Variation of Storey Drifts of (G+7) flat-slab structure

Figure-13: Variation of Storey Drifts of (G+10) flat-slab structure
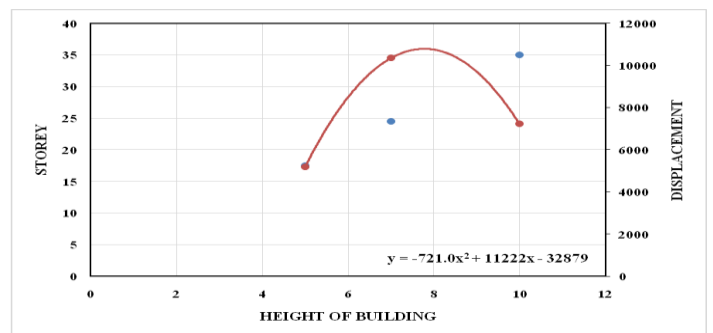

Figure-14: Variations of maximum Storey Displacements for (G+5), (G+7) and (G+10) flat-slab structure for stand-off distance 10m.
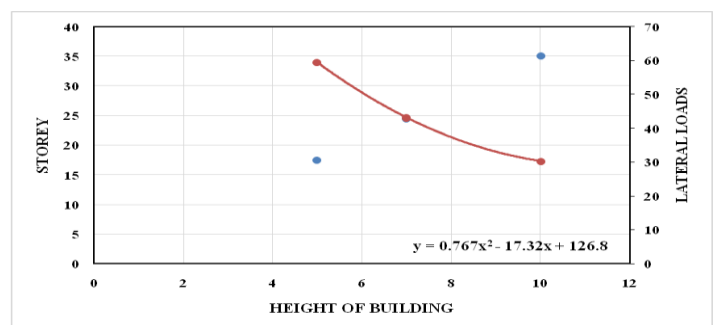

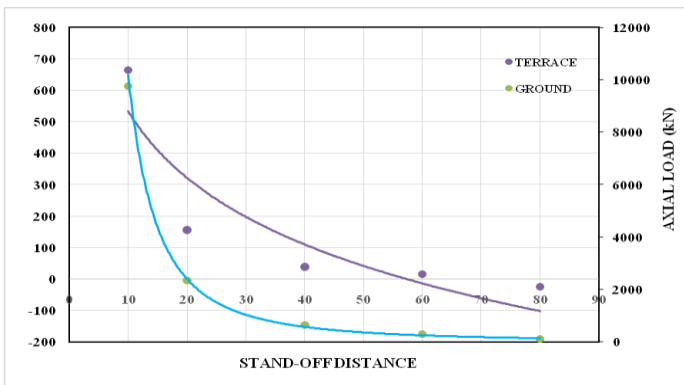**Figure-15:** Variations of Lateral loads for G+5, G+7 and G+10 flat-slab structure

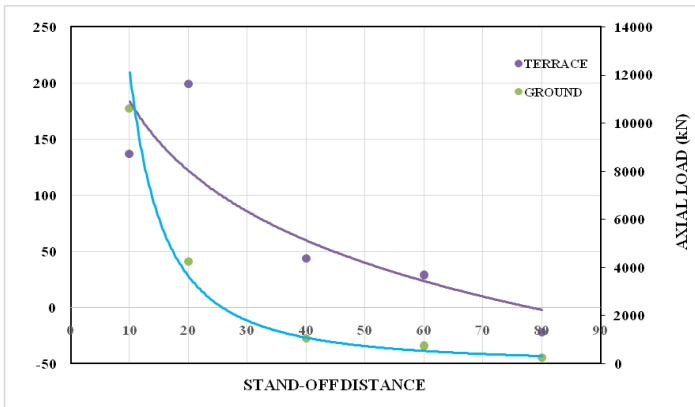**Figure-16:** Variations of axial loads on corner columns for G+5 flat-slab structure

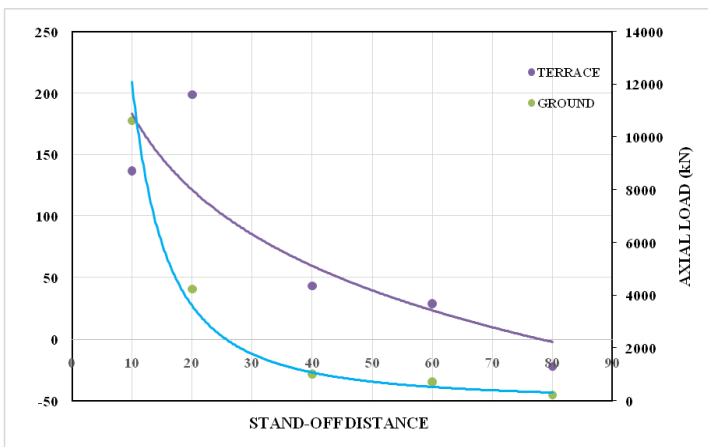**Figure-17:** Variations of axial loads on corner columns for G+7 flat-slab structure

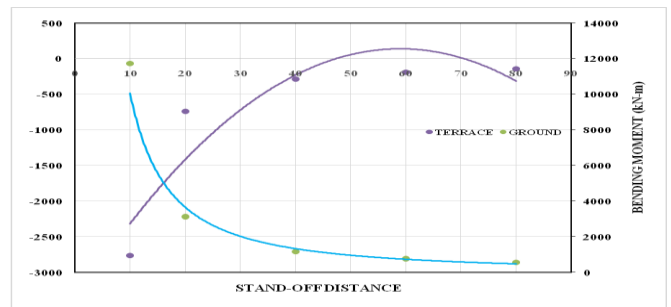**Figure-18:** Variations of axial loads on corner columns for G+10 flat-slab structure

Figure-19: Variations of bending moment on corner columns for G+5 flat-slab structure
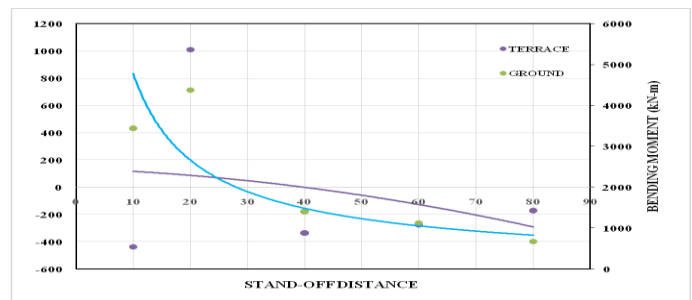

Figure-20: Variations of bending moment on corner columns for G+7 flat-slab structure
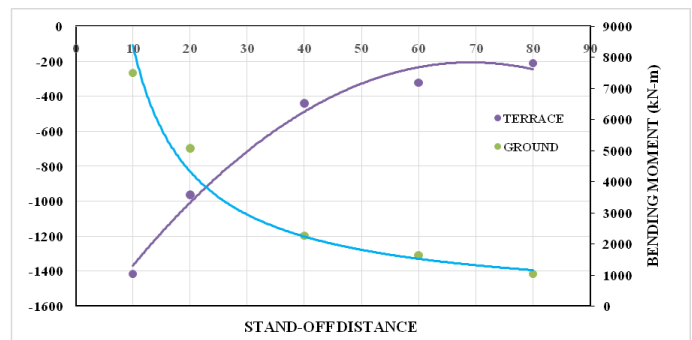

Figure-21: Variations of bending moment on corner columns for G+10 flat-slab structure

6. CONCLUSIONS

1) The storey drift evaluated for the structures with flat-slab, it is observed that the storey drift for (G+5) and (G+7) flat-slab structure is found to be greater in third-floor for stand-off distance 10m and fourth-floor for (G+10) flat-slab structure.

2) As the detonation point increases the pressure on the flat-slab structure decreases. The pressure varies inversely with stand-off distance.

3) The storey displacement for (G+5), (G+7) and (G+10) flat-slab structure decreases polynomial, as stand-off distance increases the displacement decreases.

4) The axial loads and bending moment for all columns found to be greater for on flat-slab structure and compared to conventional structure.

ACKNOWLEDGEMENT

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