PERFORMANCE OF SYMMETRIC AND UNSYMMETRIC R.C FRAMED BUILDINGS SUBJECTED TO SURFACE EXPLOSION

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Abstract - *Now a day's irregular shape of building is being mostly designed due to geometrical irregularities or dueto site shapes and or other factors. There is a need to study about these irregularities. This irregularity may be plan or vertical. Plan or vertical irregularity makes structures vulnerable. Torsional irregularity, overturning moment can rise abruptly having irregularity in a structure. Hence, effect of irregularity is a very important issue to be considered during building design. In the past few years, structures subjected to blast load gained importance due to accidental events or natural events. Generally, conventional structures are not designed for blast load due to the reason that the magnitude of load caused by blast is huge, and the cost of design and construction is very high. If blast explosion occurs inside or surrounding a building it damages the structure very badly and, in some cases, even structure collapses also. Day by day terrorists' activities are increasing and they mainly focus on the high-rise buildings, 5-star hotels and crowded places. Blast loads are dynamic loads, they should also be calculated like wind loads and seismic loads and the structures should be designed by considering the blast loads. In this view, studied the performance of ten storied R.C framed buildings having symmetric and un-symmetric plans subjected to surface explosion. The main objective of the present study is to know the behavior of irregular RC framed buildings subjected to surface explosion. Three ten storied R.C framed buildings with different shapes are considered for the study. For the analysis ETABS software has been considered.*

***Key Words*: Blast Loads, Surface Explosion, Irregular Structures**

1.INTRODUCTION

Modern buildings are being widely designed as irregular structures. A building is said to be a regular when the building configurations are almost symmetrical about the axis and it is said to be the irregular when it lacks symmetry and discontinuity in geometry, mass or load resisting elements. Asymmetrical arrangements cause a large torsion force which makes the structure torsionally irregular. There are two types of irregularities such as: 1) Horizontal irregularities refers to asymmetrical plan shapes (L, T, U and F) or discontinuities in horizontal resisting elements such as re-entrant corners, large openings cut out sand other changes like torsion, deformations and other stress concentrations, 2) Vertical irregularities referring to sudden change of strength, stiffness, geometry and mass of a structure in vertical direction.

BLAST LOADS

Blast load is dynamic in nature so all the parameters related to blast will vary with time. A bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The indirect effects can combine to inhibit or prevent timely evacuation, thereby contributing to additional casualties. In addition, major catastrophes resulting from gas-chemical explosions result in large dynamic loads, greater than the original design loads, of many structures. Blasting can also be used for demolition of structure for progressive collapse without damaging adjacent structures. These types of analysis are generally carried out by military organization or any other special departments. High explosives are solid in form and are commonly termed condensed explosives. TNT (trinitrotoluene) is the most widely known example. There are 3 kinds of explosions which are unconfined explosions, confined explosions and explosions caused by explosives attached to the structure.

2. LITERATURE REVIEW

Luccioni in 2004 [5], This paper represents the analysis of the structural failure of reinforced building caused by a blast load. Luccioni studied the effects of mesh size on pressure and impulse distribution of blast loads with the help of hydro-codes. The model was constructed following the structural plans of the actual building. The dynamic analysis was carried out for a building using AUTODYN-3D. The model was tested under the explosive of 400 kg TNT at a standoff distance of 2.5m. The results obtained for different positions of explosive charge are presented and compared. The results show that the numerical analysis accurately reproduces the collapse of the building under blast load confirming the location and magnitude of the explosion.

Herrera, Soberon in 2008 [17], have studied the influence of plan irregularities. Six structures of various shapes like rectangular, square, L, inverted L, T, U have been considered and analysed by using SAP2000. These structures were subjected to ten characteristic accelerograms of Mexican Cat Log of Strong Motion Earthquakes. The results conclude that the irregular structures are more vulnerable. The irregularity problems with plan or elevation in many cases surpasses to the lineaments established in federal district codes.

Nitesh Moon in 2009 [13], studied the response of simple RC columns subjected to constant axial loads and lateral blast loads. ANSYS was used to model the RC column with different boundary conditions. A constant axial force was first applied to the column and the equilibrium state was determined, lateral blast load was applied and the response time history was calculated. The parameters considered were the concrete strength 40Mpa for normal strength column and 80Mpa for high strength column. The blast load was calculated based on Oklahoma bombing report at a standoff distance of 5m. the free field blast wave parameters for surface burst were determined. The results conclude that the high strength column have higher lateral deflection than normal strength column. The finite element analysis revealed that for axially loaded columns there exists a critical lateral blast impulse. The column size was reduced from 500 x 900 mm for NSC column down to 350 x 750 mm for HSC column with the axial load capacities are still same.

Assal Husseinin 2010 [4], studied the analytical methods of a SDOF system analysis subjected to blast loadings. The analysis is mainly focussed on the displacement time history responses. In this study two types of blast load waves are considered for non linear analysis of SDOF system, one is simple pulse wave and second is bilinear pule wave. The results of NON SDOF program showed that the effect of type of wave on the time history analysis results and computed energy of blast.

Jayasinghe et.al in 2010 [6], studied the non-linear dynamic response of high rise buildings with setbacks and without setbacks. G + 20 storey building is considered for analysis. The modelling is done using SAP2000. The building is designed for imposed loads, dead loads and wind loads. Time history analysis is carried out for the building with a charge weight of 500kg at a standoff distance of 10m. The parameters calculated are storey drift, peak deflection, acceleration and bending moments. The results conclude that the buildings having setbacks shows the better performance in terms of peak displacement, peak acceleration and inter storey drift than the buildings that do not have setbacks. Twenty storey tall buildings with shear walls and frames that are designed for just normal loads performed well without catastrophic collapse when subjected to blast load. Frames having shear walls closer to the explosion suffer less damage when compared to the frames having shear walls further away from the explosion.

Mohammed Al-Ansari in 2012 [12], this paper compares the response of the buildings between blast loads and earthquake loads and derives a relation- ship in the form of formulas and charts. The data was obtained by several structural models with different dimensions, shapes and materials and blast loadings and earth quake loads in different zones. A six- storey building with a standoff distance of 2m subjected to blast loading of charge weight 1000kg TNT is taken. The results conclude that the response of building model subjected to blast loads with different heights and standoff distances have a similar effect to the building with small height and same standoff distance, however the height have small impact in structures subjected to blast loading. But it has strong impact on buildings subjected to earthquake loads. The analysis shows that the twenty-storey building subjected to earthquake load in zone 5 have the same response as if it is blasted with a charge weight of 128kg TNT at a standoff distance of 2m or if blasted with a charge weight of 261kg TNT at a standoff distance of 10m.

Jayashree, Rakul Bharatwaj in 2013 [7], have investigated the dynamic response of the space framed structure due to blast load. A type of fibre reinforced concrete (SIFCON) have been used as a replacement to reinforced cement concrete. SIFCON means slurry infiltrated fibre reinforced concrete. Space framed models were developed using software SAP2000. Time history analysis is carried out for the blast load. The dynamic characteristics such as fundamental frequency, mode shapes are obtained. The properties of SIFCON and RCC are derived from experiments. The displacement time history response of frames with SIFCON and RCC due to blast load is compared. The results showed that the reduction in the displacement of about 30% is achieved using SIFCON. The dynamic behaviour of SIFCON frame is better than RCC frame.

Amol Unde in 2013 [2], studied the properties of blast wave by estimating the blast wave parameters for different charge weights at different standoff distances. The model is designed for 3,4,5,6,7,8,10,12 bays of each having a floor height of 3m and each having a span of 3m. the modelling is done using STAAD PRO. The blast wave parameters are estimated for a charge weights of 0.1T, 0.2T, 0.4T, 0.6T at a standoff distance of 30m, 35m, 40m. the parameters considered are scaled distance, peak over pressure, peak reflected over pressure, positive phase duration, equivalent triangular phase duration and are calculated as per IS 4991. The results conclude that as the intensity of blast increases the positive phase duration decreases. While designing the blast resistant structures height of the structure is an important factor. During blast high tensile load is induced, hence provisions to prevent uplift should be taken on exposed side and for rear side crushing failure due to compressive load should be taken care for columns.

Kulkarni in 2014 [16], have studied the dynamic response of high rise building subjected to blast load. A 30-storey high rise building was modelled using SAP2000. The building was subjected to two different charge weights 800lbs and 1600lbs TNT at a standoff distance of 5m and 10m. The blast load analysis is carried out as per the guidelines mentioned in TM5-1300. The primary parameters are total drift and inter storey drift. The model is analysed by using no linear model analysis. The results conclude that the standoff distance is a key parameter that determines the blast pressure. The most optimum model is regular infill frame which shows the lowest value of storey drift and the structure is good in lateral stability. The most vulnerable structure is irregular frame which shows highest value of storey drift. There is no effect on upper floor as there is low intensity of pressure in upper floor due to increase in standoff distance. Therefore, increase in standoff distance decrease pressure on top floors.

3. METHODOLOGY

The present study is focused to know the performance of symmetric and unsymmetrical R.C framed buildings subjected to a surface blast load. For the study, three10 storied buildings namely MRF-SBA, MRF-SOA, and MRF-UBA are considered. Initially, all the considered buildings are designed for gravity and lateral loads (Seismic Zone-II and Wind speed of 50m/s). On the above-mentioned frames, blast load is applied. Analysis is carried out on all the buildings by Time History Analysis. From the analysis results, storey wise response (i.e., lateral displacement and vertical displacement) is studied.

3.1 GEOMETRICAL DETAILS

Size of the building:

MRF-SBA – 75m x 75m

MRF-SOA – 91.44m x 25m

MRF-UBA – 34.75m x 91.44m

Storey height – 3.0m

Total height of the building – 30m

Number of stories –10.

Moment Resisting Frame Symmetric about Both Axis (MRF-SBA)

In this case, the shape of the building is plus, the structural form is selected with columns to resist lateral loads. Two staircases and two lifts are proposed in the building. The three sides of lift opening are provided with shear walls are shown in figure 1.

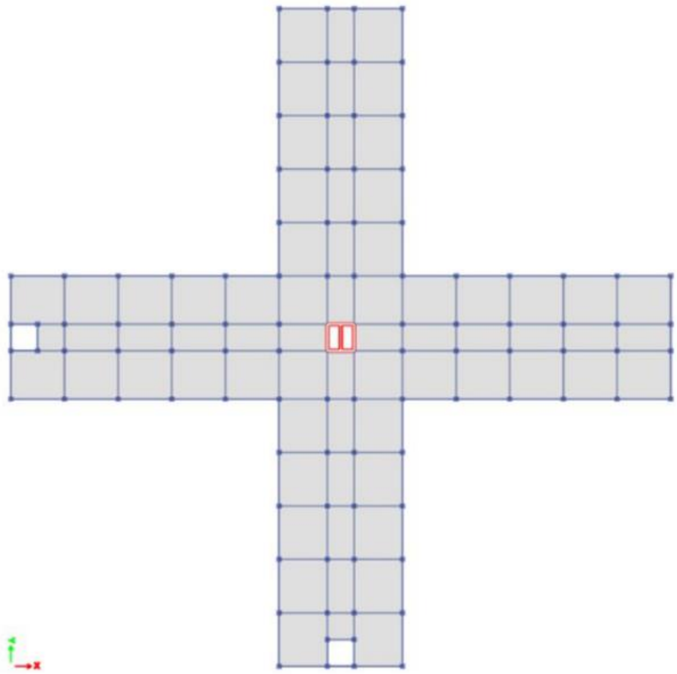

Fig 1 Moment Resisting Frame Symmetric about Both Axis (MRF-SBA)

Moment Resisting Frame Symmetrical about One Axis (MRF-SOA)

In this case, the shape of the building is inverted U, the structural form is selected with columns to resist lateral loads. Two staircases and two lifts are proposed in the building. The three sides of lift opening are provided with shear walls are shown in figure 2.

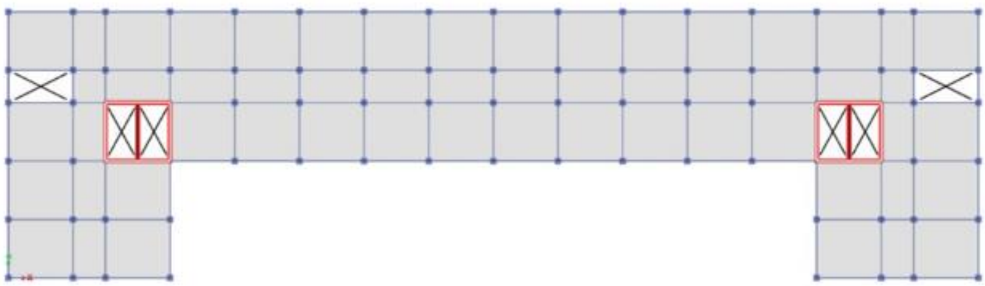

Fig 2 Moment Resisting Frame Symmetrical about One Axis (MRF-SOA)

Moment Resisting Frame Unsymmetrical about Both Axis (MRF-UBA)

In this case, the shape of the building is C with one leg long, the structural form is selected with columns to resist lateral loads. Two staircases and two lifts are proposed in the building. The three sides of lift opening are provided with shear walls are shown in figure 3.

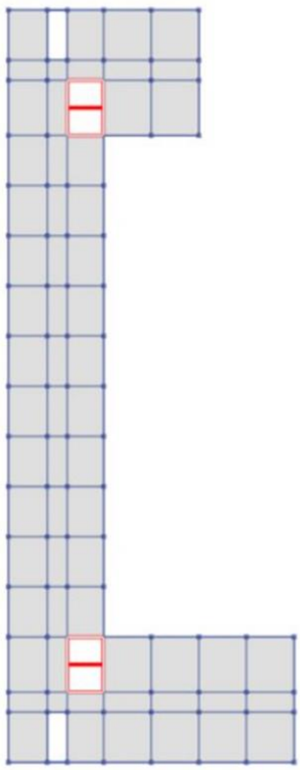

Fig 3 Moment Resisting Frame Unsymmetrical about Both Axis (MRF-UBA)

3.2 Member and Material Properties

Member and material properties are same for all the considered buildings

Column sizes = 600mm x 600mm

Beam sizes= 375mm x 600mm

Slab thickness = 150mm

Thickness of shear wall = 230mm

Grade of concrete = M30

Grade of steel = Fe500

Density of concrete = 25 kN/m^3

Density of masonry = 20 kN/m^3

Design Loads

Initially all the considered buildings are designed for the gravity and lateral loads as follows.

- **Dead Loads -** design as per IS 875(Part-1):1987
- **Live Loads -** design as per IS 875(Part-2):1987.

- **Wind Loads**

The wind load is taken as per IS 875 (Part III): 2015. A basic wind speed of 50 m/s is considered uniformly for all the alternatives.

Location of building = Visakhapatnam Basic wind Speed = 50m/s

Risk factor, K_1 = 1

Terrain Category, K_2 = 3

Topography factor, K_3 =1

Importance for Cyclone region, K_4 = 1

- **Seismic Loads**

The seismic load is considered according to IS 1893 (Part 1): 2016. Response Spectrum method is used for the analysis.

The following parameters are considered for in the seismic analysis.

Location of building = Visakhapatnam

Zone =II

Importance Factor =1.5

Soil Type = Medium (II)

Response reduction factor, R = 5

- **Blast Loads**

Loads are usually divided into static loads, quasi static loads and dynamic loads based on the time duration of an action. However, dynamic loads span over a range of time intervals. A blast is a pressure disturbance caused by rapid release of energy. Explosions caused by high explosives like TNT are called detonations whereas those caused by low explosives are called deflagration. TNT is being used as the standard benchmark, where all explosions can be expressed in terms of an equivalent charge mass of TNT. In this study 2500kg TNT at a 10.0m range is considered for the analysis. When a charge explodes, a pressure wave is formed by the explosion that applies a load on the surrounding building.

Table 1 Blast load calculations of each storey level at 10m

Location	Weight W (kg)	Height R(m) from explosion	Scaled distance Z = $R/W^{1/3}$ ($m/kg^{1/3}$)	Pso (kPa)	Ta/w ($ms/kg^{1/3}$)	Ta (ms)	Is/w ($kpa\text{-}ms/kg^{1/3}$)	Is (kpa-ms)	Tof (ms)	Ta+tof (ms)	Pr (KPa)	Pr (MPa)
Ground	2500	10.00	0.69	2900	0.24	3.39	190	2739.80	1.89	5.28	20735.00	20.74
1st Floor	2500	10.44	0.72	2800	0.26	3.69	195	2811.90	2.01	5.70	19712.00	19.71
2ndFloor	2500	11.66	0.81	2100	0.32	4.54	200	2884.00	2.75	7.29	13902.00	13.90
3rdFloor	2500	13.45	0.93	1600	0.40	5.77	240	3460.80	4.33	10.09	8960.00	8.96
4thFloor	2500	15.62	1.08	1300	0.50	7.21	230	3316.60	5.10	12.31	5551.00	5.55
5thFloor	2500	18.03	1.25	1195	0.72	10.38	210	3028.20	5.07	15.45	4397.60	4.40
6thFloor	2500	20.59	1.43	975	1.04	15.00	195	2811.90	5.77	20.76	2301.00	2.30
7thFloor	2500	23.26	1.61	755	1.30	18.75	182	2624.44	6.95	25.70	1396.75	1.40
8thFloor	2500	26.00	1.80	524	1.56	22.50	166	2393.72	9.14	31.63	901.28	0.90
9thFloor	2500	28.79	2.00	280	1.85	26.68	150	2163.00	15.45	42.13	448.00	0.45
10thFloor	2500	31.62	2.19	268	2.16	31.20	138.60	1998.61	14.92	46.12	396.64	0.40

4. RESULTS AND DISCUSSIONS

COMPARISON OF MAXIMUM LATERAL DISPLACEMENT AMONG MRF-SBA, MRF-SOA, MRF-UBA.

The results obtained from the analysis that was carried out for all the three buildings are discussed in this Chapter. The results such as "Lateral displacement" "Vertical displacement" and "Time period" as obtained at every 3 m level are plotted for all the three buildings are considered in the study.

AT GROUND LEVEL

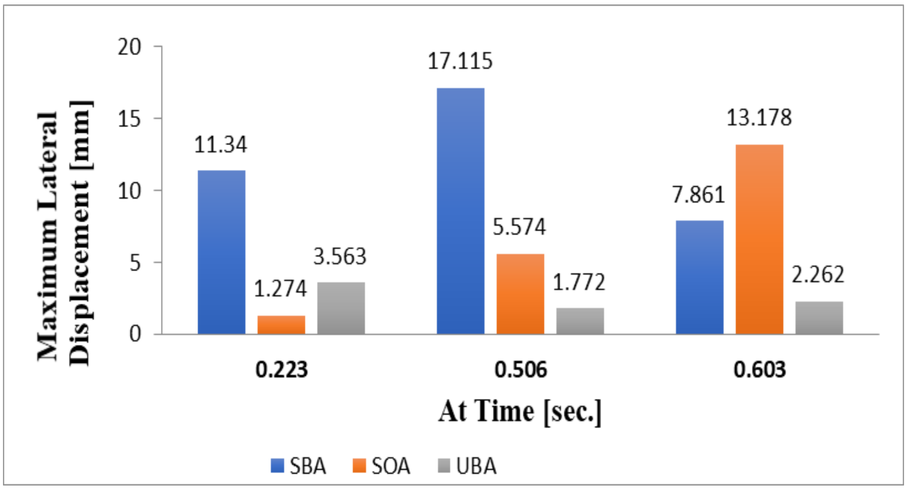

Fig. 4 Comparison of Lateral displacement at ground level of different considered models

Following are the observations made from figure 4 at different time periods.

Maximum response of MRF-SBA, SOA and UBA observed at a time period of 0.506sec, 0.603 sec and 0.223 sec respectively.

At time period of 0.223sec, observed an increase in maximum lateral displacement of MRF-SBA by 2.18 times of MRF-UBA. And there is a reduction in maximum lateral displacement of MRF-SOA by 0.64 times of MRF-UBA.

At time period of 0.506sec, observed a reduction in maximum lateral displacement of MRF-SOA by 0.67 times of MRF-SBA. And there is a reduction in maximum lateral displacement of MRF-UBA by 0.89 times of MRF-SBA.

At time period of 0.603sec, observed a reduction in maximum lateral displacement of MRF-SBA by 0.40 times of MRF-SOA. And there is a reduction in maximum lateral displacement of MRF-UBA by 0.82 times of MRF-SOA.

From figure 4, it is clearly observed that MRF-SBA has the maximum lateral displacement of 17.12mm at time period of 0.506sec.

COMPARISON OF MAXIMUM VERTICAL DISPLACEMENT AMONG MRF-SBA, MRF-SOA, MRF-UBA.

AT GROUND LEVEL

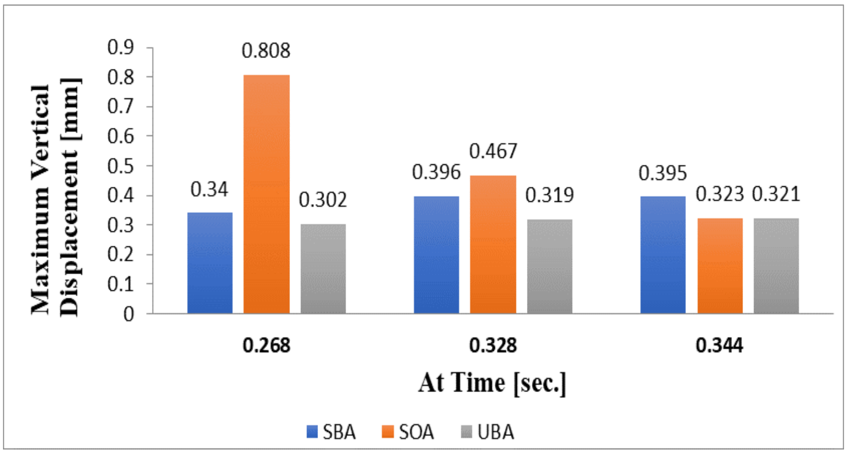

Fig. 5 Comparison of Vertical displacement at ground level of different considered models

Following are the observations made from figure 5 at different time periods.

Maximum response of MRF-SBA, SOA and UBA observed at a time period of 0.328sec, 0.268 sec and 0.344 sec respectively.

At time period of 0.268sec, observed a reduction in maximum lateral displacement of MRF-SBA by 0.58 times of MRF-SOA. And there is a reduction in maximum lateral displacement of MRF-UBA by 0.63 times of MRF-SOA.

At time period of 0.328sec, observed an increase in maximum lateral displacement of MRF-SOA by 0.18 times of MRF-SBA. And there is a reduction in maximum lateral displacement of MRF-UBA by 0.19 times of MRF-SBA.

At time period of 0.344sec, observed an increase in maximum lateral displacement of MRF-SBA by 0.19 times of MRF-UBA. And there is an increase in maximum lateral displacement of MRF-SOA by 0.006 times of MRF-UBA.

From figure 5, it is clearly observed that MRF-SOA has the maximum vertical displacement of 0.808mm at time period of 0.268sec.

CONCLUSIONS

In the present study, the analysis is done for three models of 10 storied each, namely Moment resisting frame symmetrical about both axis (MRF-SBA), Moment resisting frame symmetrical about one axis (MRF-SOA) and Moment resisting frame unsymmetrical about both axis (MRF-UBA). All the three models are analyzed and compared for the lateral displacement and vertical displacement against blast loads at different heights of the building. Following conclusions are obtained from the present study.

1. At a ground level, it is observed that MRF-SBA has maximum Lateral displacement compared to MRF-SOA and MRF-UBA.
2. At a storey level of 15.0m, it is observed that MRF-SBA has maximum Lateral displacement compared to MRF-SOA and MRF-UBA.
3. At a storey level of 30.0m, it is observed that MRF-UBA has maximum Lateral displacement compared to MRF-SOA and MRF-SBA.
4. At a ground level, it is observed that MRF-SOA has maximum Vertical displacement compared to MRF-SBA and MRF-UBA.
5. At a storey level of 15.0m, it is observed that MRF-SOA has maximum Vertical displacement compared to MRF-SBA and MRF-UBA.
6. At a storey level of 30m, it is observed that MRF-SOA has maximum Vertical displacement compared to MRF-UBA and MRF-SBA.

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