# Comparison of Building with Flag Wall and Shear Wall under Blast Loading

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***Abstract:*** The increase in the number of terrorist attacks especially in the few years has shown that the effect of blast load on building is a serious challenge that should be taken in to consideration for designing of structures. This type of loading damages the structures, externally as well as internally. Hence the blast load should be considered with same importance as earthquake load. The present study includes the comparative performance of G+14, G+19, G+24 storey building subjected to blast loading using ETABS. Different input parameters like charge weight, stand-off distance and blast pressure are conducted and analysis is carried out. Blast load analysis is carried out for 200 kg, 300 kg and 400 kg charge weight with standoff distance 10 and 20 m. The objective of this study is to effect of blast load effect on structure with single shear wall, double shear wall and Flag wall the blast is carried out.

***Key words* – Flag wall, Shear wall, Lateral resisting system, Blast load, Standoff distance, Charge weight.**

## I. INTRODUCTION

An explosion is a chemical response that releases large amount of energy and hot gases consisting of loud sound and a bright flash. It occurs within a few seconds of duration resulting of high temperature and pressure. It many countries, considering blast effects in the structural analysis and other techniques are initiated in order to project the structures and build environment. An explosion, depending on the occurrence of blast i.e., near or far from the structure, can cause ruinous damages to the internal or external frames if the structure. Thus, special care should be taken in designing the structures considering the blast load effect.

The sudden liberation of energy causes increase in temperature and pressure and so that the material present is converted into hot compressed gases. Since these gases are at high temperature and pressure, they expand rapidly creating a pressure wave which is known as shock waves. Explosion effect depends on many parameters like pressure, acceleration, velocity, etc. The distance between the blast source point and the structure is called as the standoff distance.

### a) TYPICAL BLAST WAVE PRESSURE-TIME HISTORY CURVE

In Fig. 2 shows the typical blast wave pressure-time history curve. Initially, when the explosion takes place during the arrival time of the blast waves, the pressure present in the surrounding is equivalent to the ambient pressure ($P_o$) and then it suddenly rises to peak pressure ($P_{so}$) in the fraction of second which is in the time ($t_A$) when blast wave reaches the structure. To achieve the peak pressure the time required is very small and thus it is taken as zero during the design.

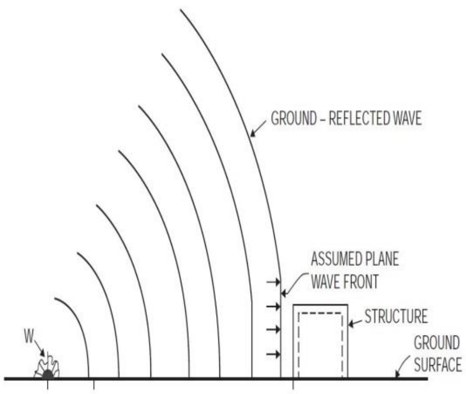



Fig. 1 Blast effect on structure

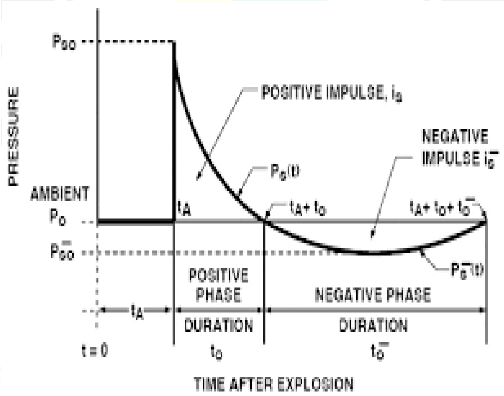



Fig. 2 Pressure-time history curve

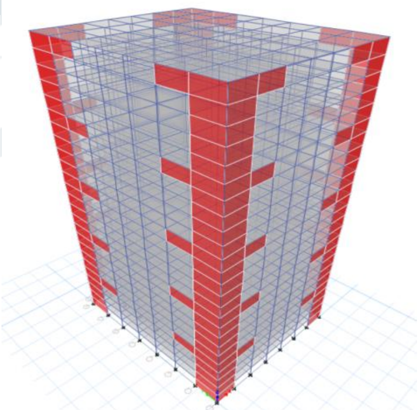


Fig. 3 Flag Wall

### b) FLAG WALL

Flag walls are reinforced concrete walls (RC walls) in selected floors, not reaching the foundation which provides additional stiffness, strength and durability to the overall structure. They can be effective in reducing overall lateral drifts, inter-storey drifts and building periods similar to outriggers (S.A. Reddy and N. Anwar, 2018). These walls behave similar to outriggers hence the main advantage using flag wall is that they do not utilize space for the operation. As in the case of the conventional outriggers trusses are involved in trying together the core and the perimeter column space in between is wasted, this space could be saved by using isolated RC walls knows as flag walls as an alternative.

## II. OBJECTIVES

- To study the performance of RC building with shear wall.
- To study the performance of RC building with flag wall.
- To study the response of RC structure with shear wall and flag wall for different charge weight.
- To study the response of RC structure with shear wall and flag wall for different standoff distance.
- To Interpretation and comparison of flag wall and shear wall in blast load.

## III. Literature Review

[4] Mr. Manoj Pillai, Roshni John, investigated that drift reduction up to 45% to 50% is achieved at 26th floor when flag wall are used.

[3] Gautham T. N., Dr. M.N. Hegde, in regular symmetrical frame least prone to damage & exhibit grate strength when compared with irregular building.

[7] S.A. Reddy, N. Anwar, flag wall can be effectively used as an alternative to shear wall to control the seismic effect on structure and flag wall placed closer to the core wall exhibit better global response.

[6] Naveenkumar Khatavakar, Dr. B.K. Raghuprasad, Maximum displacement is increased in open structure up to 55% compared to close structure.

[5] Megha S. Mahaladkar, Ramya K, the building with corner shear wall reduces the drift by 30% when compared with bare frame building.

## IV. Methodology

In present work to do blast analysis 15 storey Building is considered with 10, 20m standoff distance and 200, 300, 400 kg charge weight as a blast load. To analysis the effect of blast on structure with various structural systems i.e. Without Shear wall, With Single Shear wall, With Double Shear wall and Flag wall are considered. Maximum storey displacement, Joint velocity, Joint Acceleration is considered as a structural parameters to know the response of the buildings with blast load. Rectangular plan area (35m x 42m) with 7 bays on each axis is provided as building dimensions. Following Material and section properties are used for analysis.

| | | | | | |
|---|---|---|---|---|---|
| **1.** | **Shear Wall Thickness** | 230 mm | **2.** | **Flag wall Thickness** | 230 mm |
| **3.** | **Concrete** | M30 | **4.** | **Steel** | Fe 500 |
| **5.** | **Beam Section** | 300 x 500 mm | **6.** | **Slab Thickness** | 150 mm |
| **7.** | **Column Section** | 450 x 450 mm | **8.** | **Blast load calculation** | IS 4991:1968 |

## V. Calculation

Calculation of blast pressure for Triangular Time History nodal load as per IS 4991:1968.

a. Characteristic of Blast Load

| | |
|---|---|
| Scaled Distance, X = D/W $^{(1/3)}$ | Scaled time, to = Actual time / W $^{(1/3)}$ |
| D = Distance of the building from ground zero | W = Explosive charge in tonne |
| $P_a$ = 1.00 kg/cm$^2$ | $Q_o$ = Dynamic pressure (kg/cm$^2$) |
| $P_{so}$ = Peak side-on overpressure (kg/cm$^2$) | $T_d$ = Duration of equivalent triangular pulse (Milliseconds) |
| $P_o$ = the ambient atmospheric pressure = 1kg/cm$^2$ | $T_d$ = value corresponding to X/W $^{(1/3)}$ (Milliseconds) |
| $P_{ro}$ = Peak reflected overpressure (kg/cm$^2$) | $T_o$ = Positive phase duration (Milliseconds) |
| a = 344 m/s (velocity of Sound in air) | $T_o$ = value corresponding to X/W $^{(1/3)}$ (Milliseconds) |
| M = $\{1+(6/7)(P_{so}/P_a)\}^{(1/2)}$ | U = (M*a) m/milliseconds |

b. Pressure Calculation

The calculations of pressure with 200kgs/0.2tonne TNT charge weight & standoff distance of 10m. Structure dimension (i.e. L= 35m, B=42 m, H=45 m, Floor Height S = 3 m) is used for calculation of blast pressure.

Actual Distance = $(x2+y2+z2)^{(1/2)}$ = 27.67

Scaled distance x = {actual distance/ (0.2)} $^{(1/3)}$ = {27.67/(0.2)} $^{(1/3)}$ = 47.31 m

Take $P_a$ = 1.00 kg/cm$^2$ (Table-1 IS-4991-1968)

Linearly interpolation between 45m and 48m for the scaled distance 47.31m,

$P_{so}$ = 0.606 kg/cm$^2$  $P_{ro}$ = 1.5 kg/cm$^2$  $q_o$ = 0.121 kg/cm$^2$

The scaled times to and td obtained from table-1 for scaled distance 47.31m,

$t_o = \{32.02(0.2)\}^{(1/3)}$ = 18.72 milliseconds

$t_d = \{22.44(0.2)\}^{(1/3)}$ = 13.12 milliseconds

$M = \{1+(6/7)(P_{so}/P_a)\}^{(1/2)}$ = 1.23

a = 344 m/s (velocity of sound in air which may be taken at mean sea level at 200$^o$ C)

U = M*a = 424.03 m/s = 0.424 m/millisecond

$t_c$ = 3S/U = 21.22 milliseconds > $t_d$

$t_t$ = L/U = 99.05 milliseconds > $t_d$

$t_r$ = 4S/U = 28.30 milliseconds > $t_d$

As $t_r > t_d$ no pressure on the back face are considered

For roof and sides Cd = -0.4 (Table-2 IS-4991-1968)

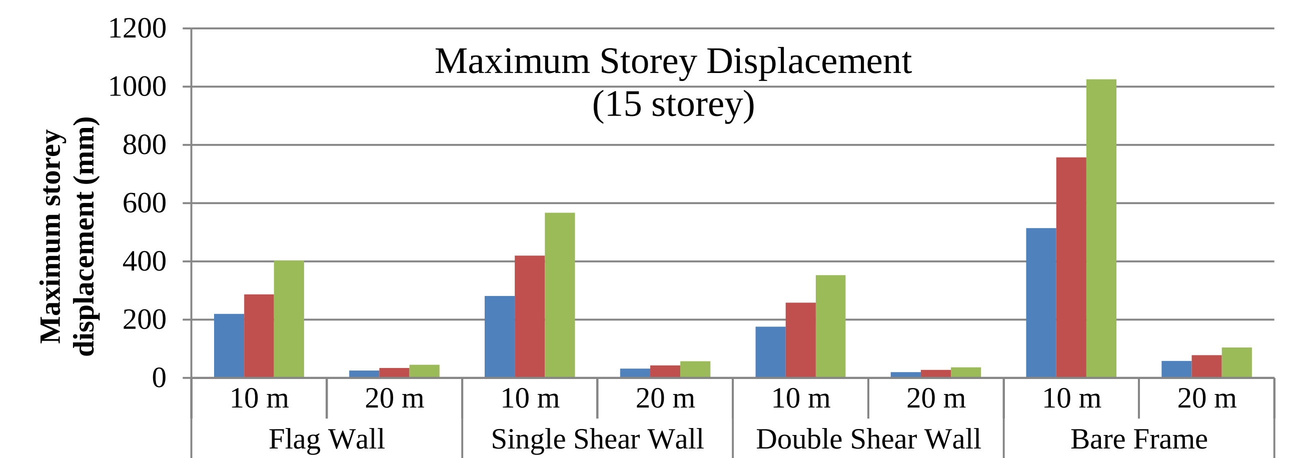
$P_{so}+C_d*q_o$ = 0.606+ {(-0.4)*0.121} = 0.55 kg/cm$^2$

**Front face loading = 147.15 kg/cm$^2$**

**Side face loading = 53.955 kg/cm$^2$**

## VI. Result

- Maximum Storey Displacement:




| | Flag Wall | | Single Shear Wall | | Double Shear Wall | | Bare Frame | |
|---|---|---|---|---|---|---|---|---|
| | 10 m | 20 m | 10 m | 20 m | 10 m | 20 m | 10 m | 20 m |
| 200 Kg | 219.38 | 24.52 | 280.76 | 31.35 | 174.774 | 19.62 | 513.82 | 57.58 |
| 300 Kg | 285.96 | 33.01 | 419.62 | 42.17 | 257.57 | 26.4 | 756.55 | 77.5 |
| 400 Kg | 402.51 | 44.35 | 566.48 | 56.55 | 352.12 | 35.45 | 1024.23 | 104.139 |

Fig. 4 Maximum Story Displacement

- Joint Acceleration:

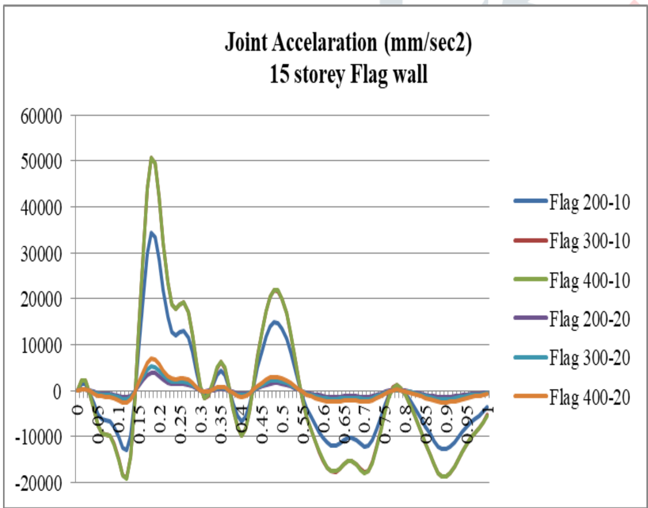



Fig. 5 Joint Acceleration for Flag wall

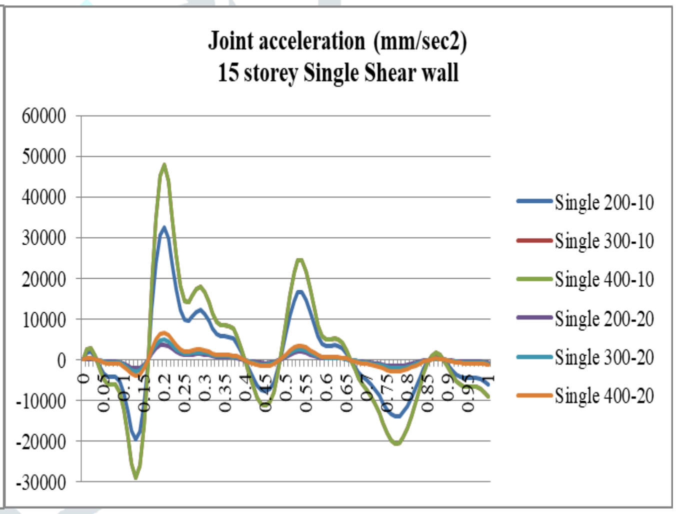



Fig. 6 Joint Acceleration For Single shear wall

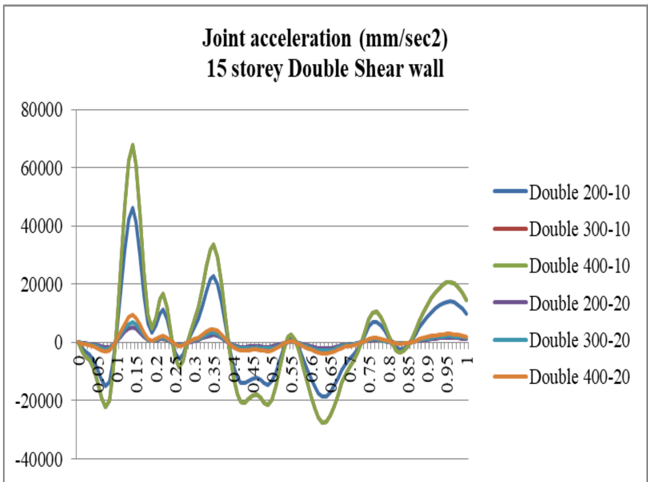



Fig. 7 Joint Acceleration for Double shear wall

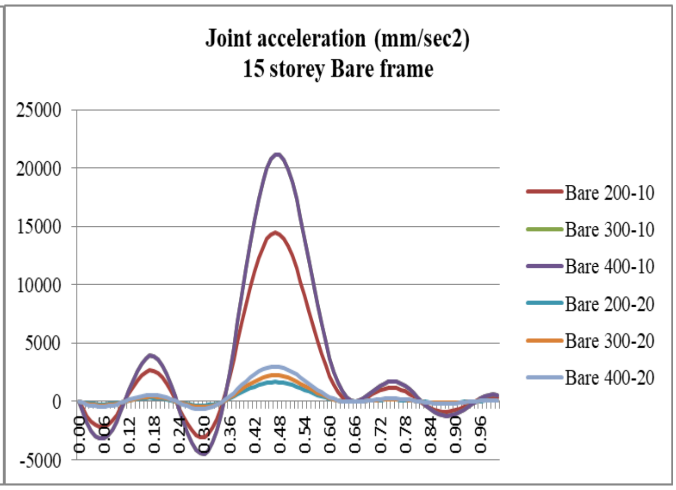



Fig. 8 Joint Acceleration for Bare frame

- Joint Velocity

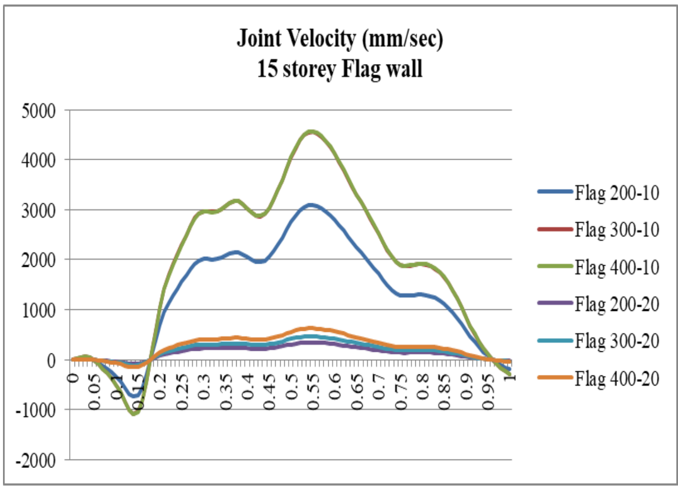



Fig. 9 Joint Velocity for Flag wall

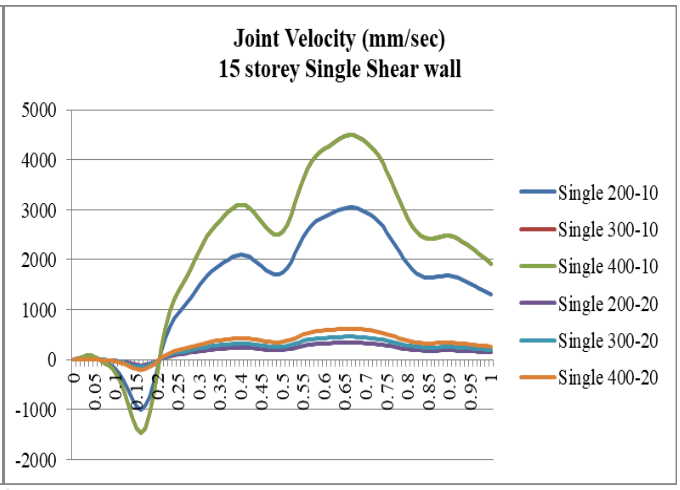



Fig. 10 Joint velocity for Single shear wall

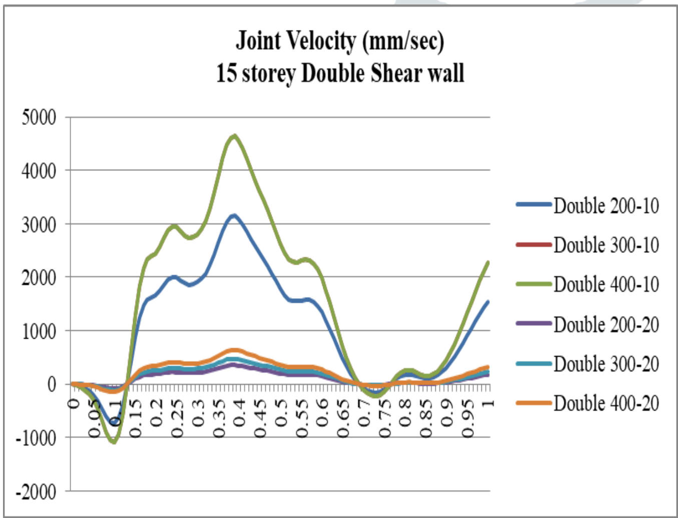



Fig. 11 Joint velocity for Double shear wall

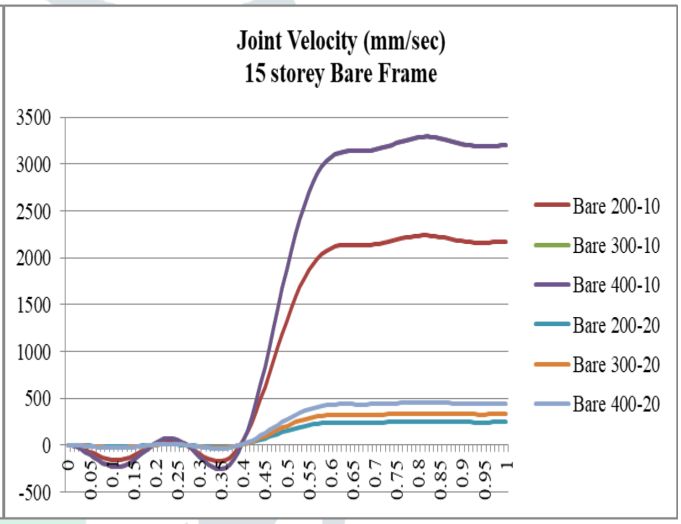



Fig. 12 Joint velocity for Bare frame

## V. CONCLUSION

- Maximum storey displacement is less in flag wall compared to single shear wall.
- If charge weight is less than 200kg and standoff distance is more than 20m will not much effect on bare frame structure.
- If charge weight is less than 300kg and standoff distance is more than 20m will not much effect on fag wall structure.
- Base shear is more in double shear wall.
- Maximum storey displacement is varies up-to 55.85%, 43.44%, 61.81% with flag wall, single shear wall, double shear wall respectively compared to bare frame structure in 15 storey for charge weight 200kg.
- Maximum storey displacement is varies up-to 59.44%, 40.03%, 67.26% with flag wall, single shear wall, double shear wall respectively compared to bare frame structure in 15 storey for charge weight 300kg.
- Maximum storey displacement is varies up-to 60.70%, 44.69%, 66.56% with flag wall, single shear wall, double shear wall respectively compared to bare frame structure in 15 storey for charge weight 400kg.
- So overall performance of flag wall is good for blast resistance.

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IS codes:

1. IS:4991-1968 "Criteria for blast resistant design of structure for explosions above ground"