Parametric Study of Multi – Storeyed Steel Building under Different Type of Blast Loading

Harsh D. Kakadiya [1], Abbas Jamani [2]
[1]Dept of Structure Engineering
[2]Assistant Professor, Dept of Structure Engineering
[1, 2] LJIET, AHMEDABAD, Gujrat, India

Abstract- *The drastic damage to the property and lives due to the recent terrorist attacks on the infrastructure has led to the need of extensive research on the progressive collapse analysis of multi-storey building subjected to blast loading. Generally, research has been done based on the APM (Alternative Path Method) with sudden column removal by ignoring the preferable location of blast loading. In this thesis, 3D model of 20 storey steel building with direct simulation of blast load is proposed. Also, the effect of blast loading at various locations has been evaluated. Two types of blast events have been considered i.e. vehicle borne and package bomb at a same time. The blast load is analytically determined by the numerical model of structure which was prepared using the "SAP2000" software. The numerical model is validated with the published example of 20 storey tall building subjected to blast load. Based on the finite element analysis result, recommendations have been proposed to control the collapse of the steel buildings.*

Keywords- Steel Structure, Blast, SAP2000, APM, Collapse, Vehicle Bomb, Package Bomb, 20 Storey.

I. INTRODUCTION

Upgradation of the building for a "certain level" of resistance against terrorist attacks may not be significant as compared to the overall lifetime costs of the building including the land value, and security monitoring. A bomb explosion within or around a building can have catastrophic effects, damaging and destroying internal or external portions of the building. It blows out large framework, walls and doors/windows and shuts down building services. The impact from the blast causes debris, fire and smoke and hence can result in injury and death to occupant. Bomb damage to building depends on type and layout of the structure, material used, range of the located explosive device and the charge weight. A steel frame structure is a conventional structural system in the regions with high seismic intensity. Research on the progressive collapse analysis of steel frame structures has attached many researches. Early attempts at blast resistance design necessarily relied on judgment, test, and trial and error construction to find the best solutions, as technology improved; designers became better able to predict the influence of explosions and the resistive responses that they strove to impact into their designs.

Yang Ding [1] shows that gravity columns are heavily affected by the blast loading while moment column are effective in resisting blast loading. Yang Ding [1] also shows that the risk of VBIED (Vehicle Borne Improvised Explosive Device) are heavy in case of exterior column, so, the structure with moment frame at exterior face is key for good resistance against explosion.

H.M.Elsanadedy [2] analyze the 6 storey steel framed building located in Riyadh subjected to terrorist attack and provide the preventive measure for reducing impact of blast load by restricting the access of the vehicles to the building through perimeter control. If this is not possible, then outer exposed ground storey column may need to be strengthen by concrete encasement or addition of steel plates or by providing diagonal bracing or shear wall or by double walled façade system.

Feng Fu [3] analyze the 20 storey building for internal blast event and concluded that the package bomb can only cause localized structural member damage, also it is hard to trigger the whole building. This effect can be reduced by enhancing shear capacity and increase ductility of column.

Jenny Sideri [4] shows that the large column section of building with perimeter moment resisting frames act as safety valve to ensure the system's structural integrity after the end of the blast attack. He also investigates for building with interior RC rigid core and conclude that the exterior column cannot stabilize the overall system's response. Yang Ding [5] analyze for steel frame subjected to confines explosion and post explosion fire and conclude that the MRF (Moment Resistance Frame) columns are suggested to provide at the exterior face also he conclude that the weakest portion is peripheral compartment for only fire case but corner compartment is subjected to combined hazard case.

1.1 Failure Analysis

When the blast load applies on structure, sometimes some element can damage or fail and sometimes whole structure can collapse due to blast load. When the shock wave reaches the surface of steel building, the columns located at surface of explosion are subjected to large stress compared to inner element. So, failure analysis in terms of blast loading on steel structure, the shock waves through which components fail and amount of failure can be analyzed and study out what are the remedial measures is to be select for preventing the structure against blast charge and the cost effect for blast loading on structure are carried out. Deflected shape of structure is shown in fig 2.

II. NUMERICAL STUDY

In the numerical study carried out herein, the G+20 storey steel building is considered. Figure 1 and 2 show 3D view and elevation of steel building in SAP2000.

The details for generating structural model in the software are given as follow:

Height of parking storey: 3.5 m
Height of storey (other than parking): 3 m
Span of bay in X direction: 7.5 m
Span of bay in Y direction: 6.25 m
Plan dimension of building: 37.5 x 37.5 m
Number of storey: G + 20
Grade of steel: Fe 345

Loading: Dead Load, Live Load, Wind Load, and Blast Load.

Load combination consider for blast load are
1.2DL+LL+BL
DL+0.35LL+BL
DL+0.25LL+BL

Comparative analysis is carried out for the same for different criteria like displacement, stress and cost impact.

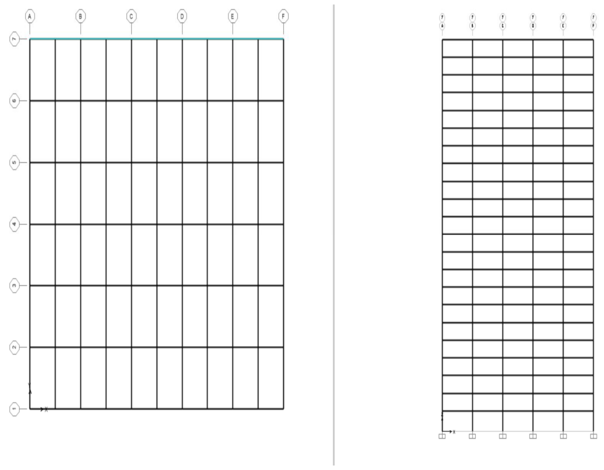

Fig 1 Plan And Elevation Of Steel Building

2.1 Problem Description

First of all, consider the buildings subjected to a blast equivalent in yield to some tons of TNT (Trinitrotoluene) at a certain standoff distance. Problem description is as follow:
Intensity of blast is taken as the 0.1t, 0.2t and 0.3t for external blast event i.e. VBIED and 0.025t and 0.015t for internal blast event. Stand-off distance for external blast event is taken as 10 m and 20 m. For internal blast event four number of position are taken into consideration i.e. Corner column at parking, Centre column at parking first storey, at mid storey, at top storey. Total no of model analzed are 60.

III. BLAST LOAD CALCULATION

Based on the specification to IS 4991: 1963, blast load pressure on the building in form of a triangular load is calculated as follows:

Characteristic of Blast
Scaled Distance, X = D/W [9]
Where, D = Distance of the building from the ground zero
W = Explosive charges in Tonne
Here, assuming $P_a = 1.00$ kg/cm^2 (Ambient Air Pressure)

Internal blast pressure is calculated as
$\Delta P = 13\ (W/V)$ [6]
Metric pressure is in bar, W is the mass of explosive in kg, V is the confined volume of air in cubic meter.

Blast Parameters

For the value of scaled distance, various blast parameters are selected from the table 1 of IS 4991:1968.

These parameters are:

- P_{so} = Peak Side on Overpressure (kg/cm^2)
- P_{ro} = Peak Reflected Overpressure (kg/cm^2)
- Q_0 = Dynamic Pressure (kg/cm^2)
- T_d= Duration of Equivalent Triangular Pulse (Milliseconds)
- T_0 = Positive Phase Duration (Milliseconds)
- T_d = Value corresponding to $X/W^{1/3}$
- T_0 = Value corresponding to $X/W^{1/3}$

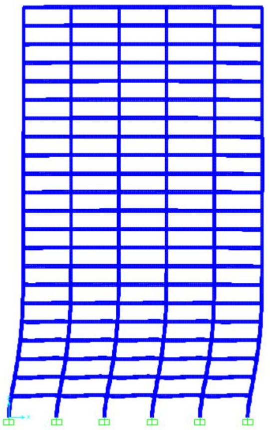

Fig 2 Deflected Shape of Building

IV. EXPERIMENTAL RESULTS

Comparing the result for different geometries with different loading condition for displacement and stresses.

4.1 Displacement

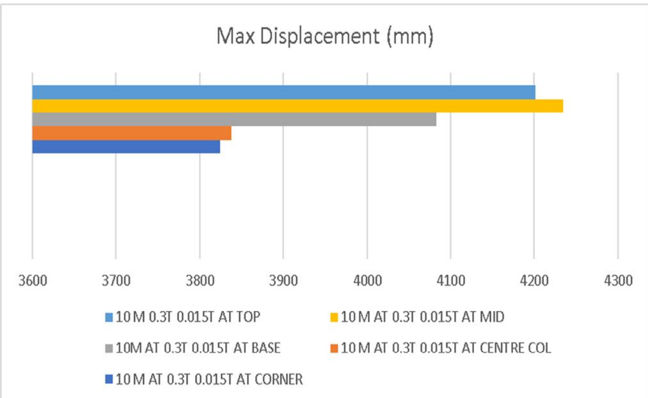

Chart-1 Displacement for value of combination of 10 m at 0.3t and 0.015t as internal blast

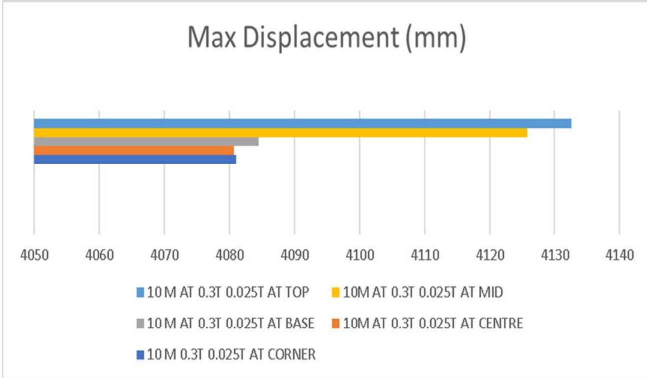

Chart-2 Displacement for value of combination of 10 m at 0.3t and 0.025t as internal blast

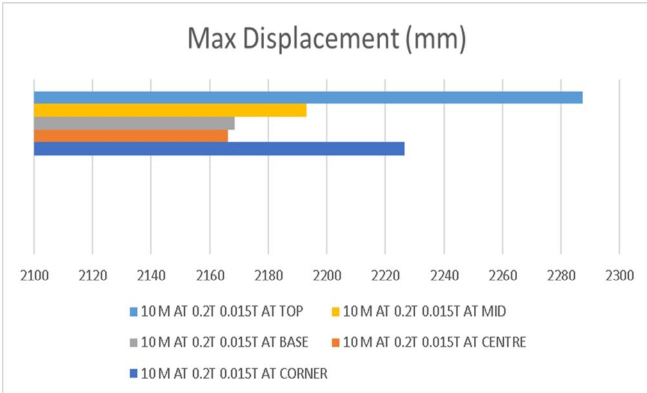

Chart-3 Displacement for value of combination of 10 m at 0.2t and 0.015t as internal blast

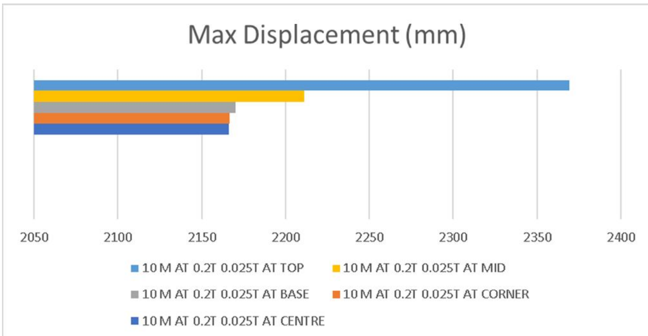

Chart-4 Displacement for value of combination of 10 m at 0.2t and 0.025t as internal blast

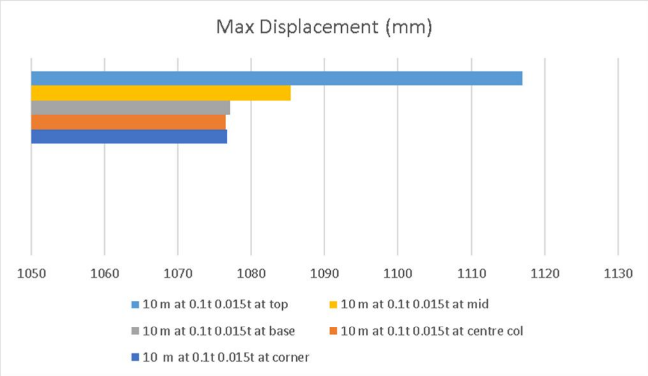

Chart-5 Displacement for value of combination of 10 m at 0.1t and 0.015t as internal blast

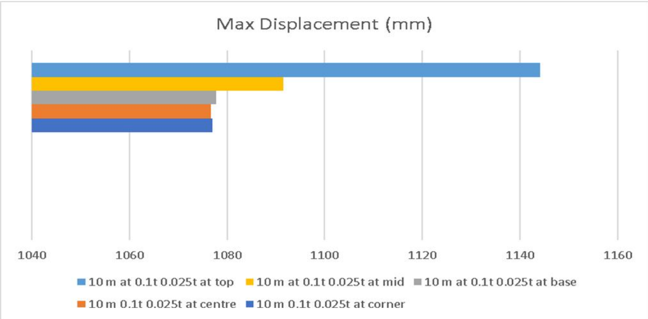

Chart-6 Displacement for value of combination of 10 m at 0.1t and 0.025t as internal blast

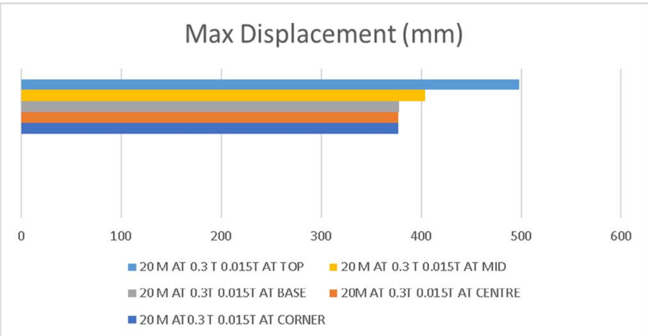

Chart-7 Displacement for value of combination of 20 m at 0.3t and 0.015t as internal blast

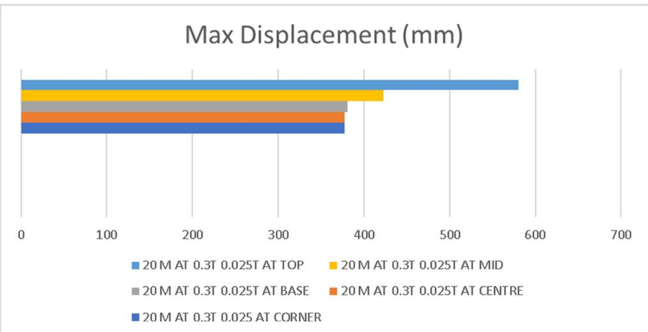

Chart-8 Displacement for value of combination of 20 m at 0.3t and 0.025t as internal blast

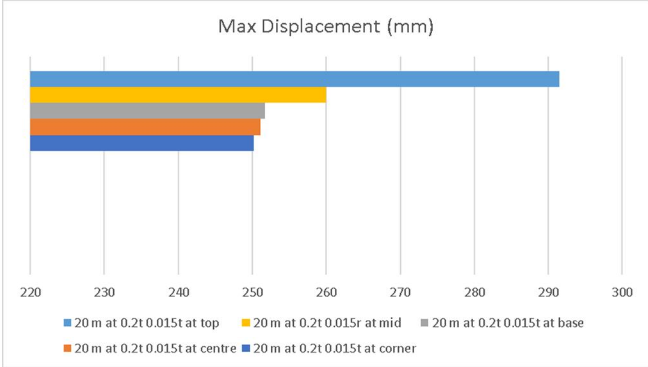

Chart-9 Displacement for value of combination of 20 m at 0.2t and 0.015t as internal blast

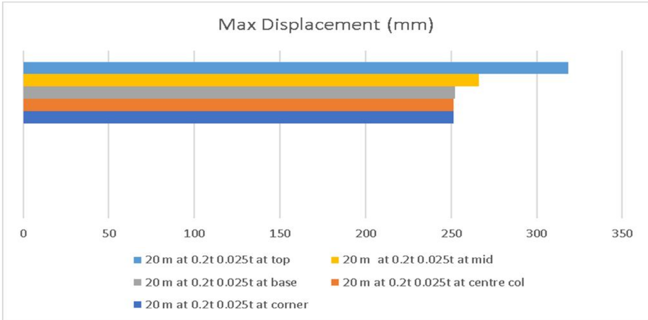

Chart-10 Displacement for value of combination of 20 m at 0.2t and 0.025t as internal blast

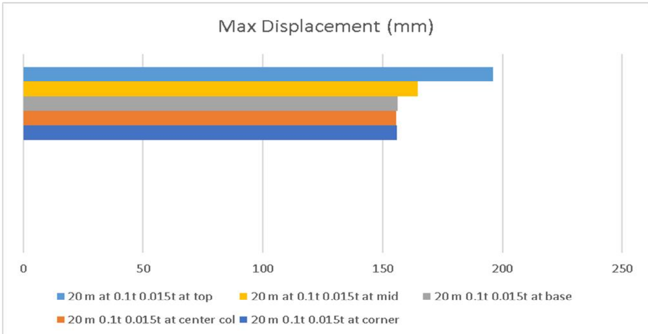

Chart-11 Displacement for value of combination of 20 m at 0.1t and 0.015t as internal blast

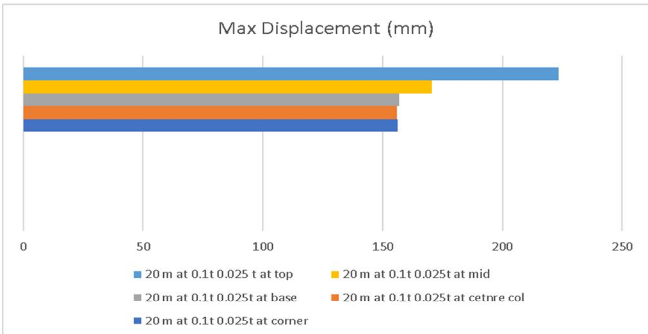

Chart-12 Displacement for value of combination of 20 m at 0.1t and 0.025t as internal blast

4.2 Stress Result

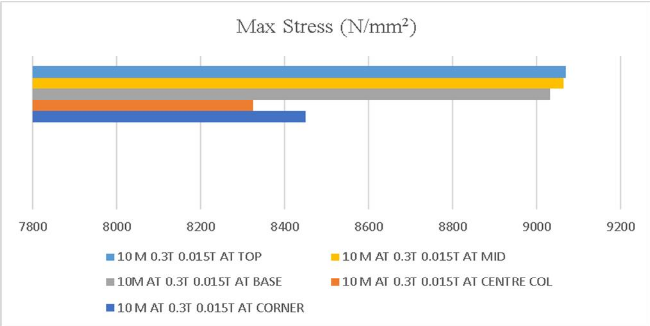

Chart-13 stress for value of combination of 10 m at 0.1t and 0.015t as internal blast

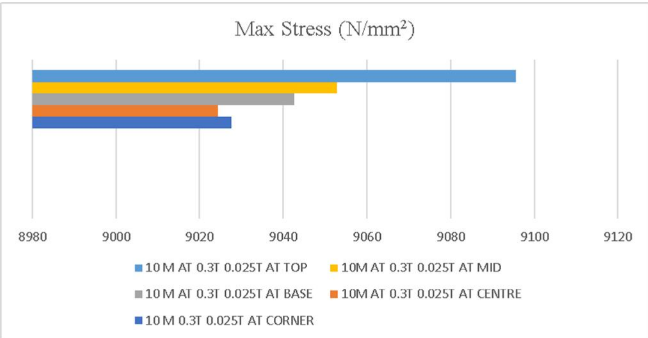

Chart-14 stress for value of combination of 10 m at 0.1t and 0.025t as internal blast

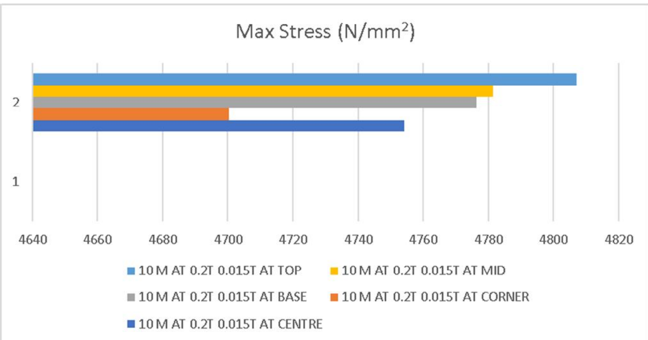

Chart-15 stress for value of combination of 10 m at 0.2t and 0.015t as internal blast

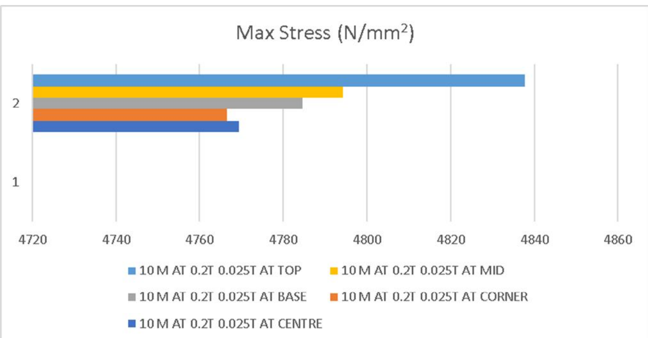

Chart-16 stress for value of combination of 10 m at 0.2t and 0.025t as internal blast

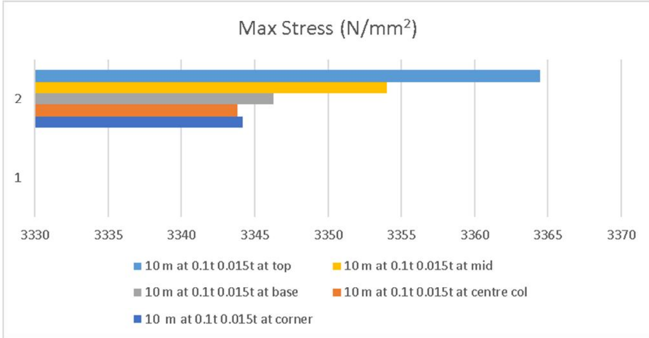

Chart-17 stress for value of combination of 10 m at 0.1t and 0.015t as internal blast

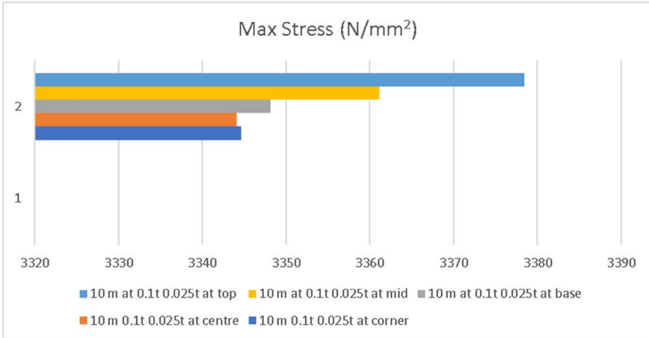

Chart-18 stress for value of combination of 10 m at 0.1t and 0.025t as internal blast

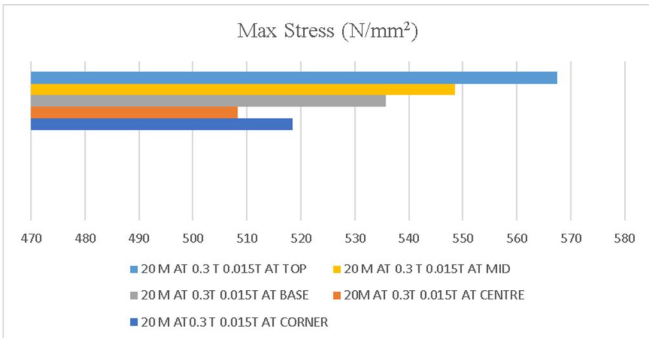

Chart-19 stress for value of combination of 20 m at 0.3t and 0.015t as internal blast

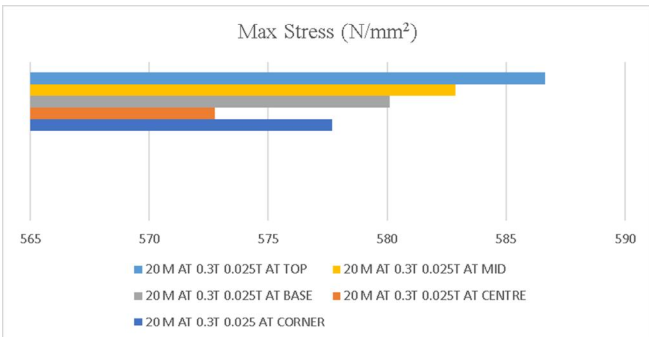

Chart-20 stress for value of combination of 20 m at 0.3t and 0.025t as internal blast

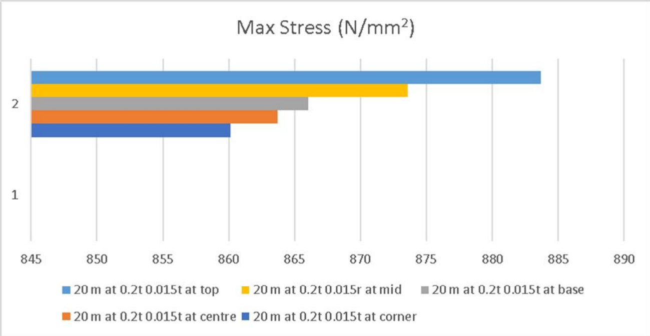

Chart-21 stress for value of combination of 20 m at 0.2t and 0.015t as internal blast

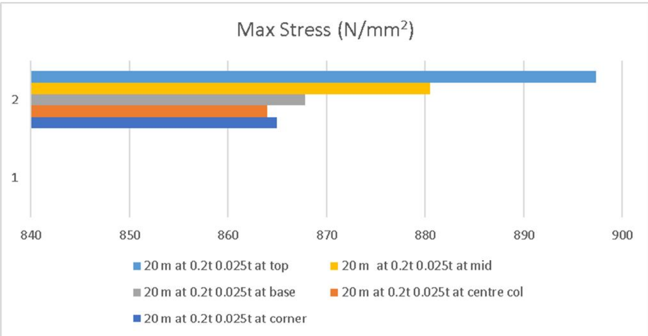

Chart-22 stress for value of combination of 20 m at 0.2t and 0.025t as internal blast

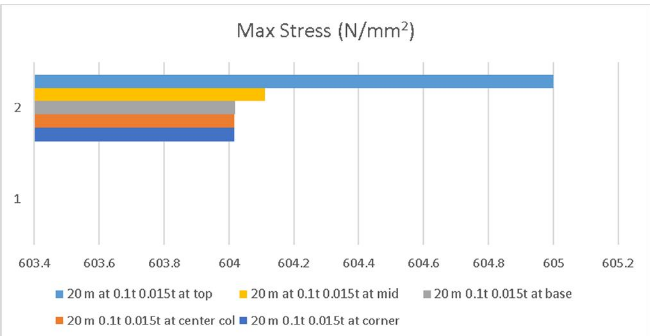

Chart-23 stress for value of combination of 20 m at 0.1t and 0.015t as internal blast

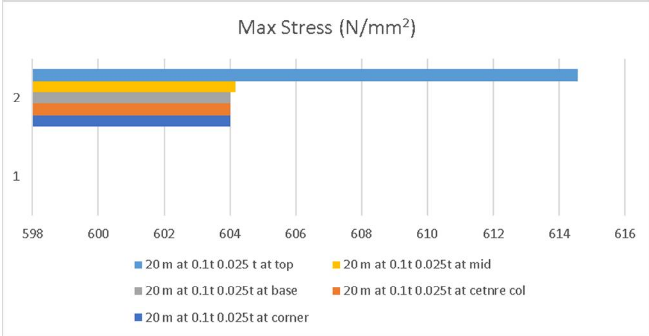

Chart-24 Stress for value of combination of 20 m at 0.1t and 0.025t as internal blast

V. CONCLUSION

According to results we can conclude that the highest charge 10 m with 0.3 tonne as external blast and internal blast as 0.025 tonne at top location provide the maximum stress value and maximum displacement.

So, the same cross section properties through out the all storey should be incorporated for blast resistance design.

It is recommended that proper take care of explosion should be taken for the important structure, or proper security should be managed so that explosion should be away as far as possible from the structure and tree plantation and any other obstacles are should be placed in front of structure to resist blast load and protect the structure.

VI. ACKNOWLEDGEMENT

I would like to thank God Almighty for granting me health and knowledge for completing this work. I am indebted to Asst. Prof. Abbas Jamani, for helping me to find out significant topic, and with his help I was able to gather scholarly sources. I would like to thank all faculty members of Civil Engineering Department, LJIET for providing all kind of possible help throughout this work. I am extremely grateful to my parents, sister, brother and friends for the support and constant encouragement they have given me throughout the stretch of this work.

REFERENCES

[1] Yang Ding, Xiaran Song, Hai tao zhu, "Probabilistic progressive collapse analysis of steel frame structure against blast loads", Engineering Structure, 2017,147,679-691, http://dx.doi.org/10.1016/j.engstruct.2017.05.063 ELSEVIER.

[2] H.M.Elsanadedy, T.H. Almusallam, Y.R. Alharbi, Y.A. Al –salloum, H.Abbas , “Progressive collapse potential of a typical steel building due to blast attacks”, Journal of constructional Steel Research ,2014.,101,143–157, http://dx.doi.org/10.1016 /j.jcsr.2014.05.005 , ELSEVIER.

[3] Feng Fu, “Dynamic response and robustness of tall building under blast loading”, Journal of Constructional Steel Research ,2013, 80, 299-307 , http://dx.doi.org/10.1016 /j.jcsr 2012.10.001,ELSEVIER.

[4] Jenny Sideri,Chris Mullen,Simos Gerasimidis,George Deodatis, “Distributed column damage effect on progressive collapse vulnerability in steel building exposed to an external blast event”, Journal of Performance of Constructed Facilities, 06/10/17,© ASCE.

[5] Yang Ding , Ye Chan , Yanchao Shi, “Progressive collapse analysis of a steel frame subjected to confined explosion and post explosion fire”, Advances in Structural Engineering ,2016, 1-17, ©Sage Publications Inc.

[6] NWC TP 6089 “Peak Overpressure For Internal Blast”, NAVAL WEAPONS CENTER CHINA LAKE, CALIFORNIA 93555,1979

[7] UFC 3-340-02, “structure to resist the effects of accidental explosions”, Unified Facilities Criteria, December 2008.

[8] GSA, “Progressive collapse analysis and design guidelines for new federal office buildings and major modernization projects”, General Service Administration, June 2003.

[9] IS 4991 (1968): Criteria for blast resistance design of structures for explosions above ground [CED 39 : Earthquake Engineering].

[10] John M. Biggs “introduction to structural dynamics”, ,McGraw Hill Company,ISBN No : 07-005255-7.

[11] C. V. R. Murty ,“guidelines on measures to mitigate effects of terrorist attacks on buildings”, Indian Institute of Technology, Kanpur, Document No : *IITK-GSDMA*.