PARAMETRIC STUDY OF RCC, STEEL AND COMPOSITE STRUCTURES UNDER BLAST LOADING

Ganganath C P [1], Lekshmi L[2]

[1]*PG Student, Dept. of Civil Engineering, Vimal Jyothi Engineering College, Kerala, India*
[2]*Asst. Professor, Dept. of Civil Engineering, Vimal Jyothi Engineering College, Kerala, India*

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Abstract - *A bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames. In this research work low rise and high rise building comparisons are taken into consideration in which same blast loading conditions are applied to all the structures and analysis results have been compared to check the suitability of RCC, steel and composite low rise and high rise buildings under blast loading conditions. ETABS v.15 is used for the parametric study. The G+10 structures are highly affected by the blast loads even though the standoff distance and the charge of explosions are the same as that of G+2 structures. The steel plate shear walls are more helpful in decreasing the maximum storey displacement occurring in a RCC structure and SPSW reduces the displacement by 98% than in the case without shear wall.*

***Key Words*: Parametric Study, Composite structures, maximum storey displacement, blast loading.**

1. INTRODUCTION

The increase in the number of terrorist attacks especially in the last few years has shown that the effect of blast loads on buildings is a serious matter that should be taken into consideration during the design process. An explosion is result of very rapid release of energy within a limited space which occurs from chemical, mechanical and nuclear sources. An explosive which is buried completely or partly below the ground surface will cause a ground shock. The explosions are mainly classified as physical and nuclear or chemical explosions.

Nowadays RCC structures and steel structures are generally constructed but a new form of structures known as composite structures also come into considerations. It is very difficult to know that in case of a low rise buildings as well as high rise buildings which type of structure will be more economical and also provides considerable strength. Generally high rise buildings are preferred to be constructed as a steel structure and low rise as RCC structures but composite structures can make our structure more economical and strong. In this research work, parametric study of Steel, RCC and Composite structures are made for low rise and high rise buildings based on different standoff distances and different types of explosion.

The explosions are mainly classified as physical and nuclear or chemical explosions. In physical explosions, energy may be released from the catastrophic failure of a cylinder of compressed gas, volcanic eruptions or even mixing of two liquids at different temperatures. In a nuclear explosion, energy is released from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the interacting nuclei, whereas the rapid oxidation of fuel elements (carbon and hydrogen atoms) is the main source of energy in the case of chemical explosions. When an explosion takes place, the expansion of the hot gases produces a pressure wave in the surrounding air. As this wave moves away from the centre of explosion, the inner part moves through the region that was previously compressed and is now heated by the leading part of the wave.

The present research is limited to air burst or surface burst. This information is used to determine the dynamic loads on surface structures that are subjected to such blast pressures and to design them accordingly. It is maintained that surface structure cannot be protected from a direct hit by a nuclear bomb; it can however, be designed to resist the blast pressures when it is located at some distance from the point of burst. There are no researches done to find the suitability of the structures in blast loading conditions. So here a comparison study is done to find the response and suitability of different type of G+2 and G+10 storied buildings at blast loading conditions and also to create methods to improve the design of buildings of serviceable operations in the event of an explosive attack. From this the critical distance below which structure is damaged and the critical type of explosion can be determined.

The main objectives of the study are given below

- To compare the G+2 and G+10 storied buildings based on their responses to the blast loading.
- To check the suitability of RCC, steel and composite G+2 and G+10 buildings under blast loading conditions.
- To check the effect of shear walls in increasing the blast resisting capacity of buildings.

2. METHODOLOGY

The modeling is done using ETABS software for G+2 and G+10 stories, among that RCC, Steel and composite structures are considered (in composite beam with RCC and columns with CFST). The standoff distances considered are 0.01km and 0.03km. Here it is considered 2 types of explosions as blast of 0.1 and 0.3 tonne. The blast loads are calculated as per IS 4991:1968 and the parameter to be compared is the storey maximum displacements. Here the RCC shear walls with 200mm thickness, steel plate shear wall with 25mm are selected and are placed at each corner edge of the structures.

2.1 Material Properties

a) Concrete Material Details (M30)

Weight per unit volume: 25 kN / m3
Modulus of elasticity, E : 25000 MPa
Poisson's ratio, U: 0.2

The structural details of the selected sections are tabulated in Table 1

Table -1: Structural Details of sections

1. **Concrete Column Section.**	
Section shape	Concrete rectangular
Dimension	375 mm x 375 mm
2 .Concrete Beam Section	
Section shape	Concrete rectangular
Dimension	230 mm x 460 mm
Cover to top bars	60 mm
3. Steel Beam Section	
Section shape	Rectangular hollow tube section
Dimension	230mm x 460 mm
4. Steel Column Section	
Section shape	Rectangular hollow tube section
Dimension	375 mm x 375 mm
5. Composite beam section	
Section shape	Rectangular
Depth	460 mm
Width	230 mm
Cover to top bars	60 mm
Cover to bottom bars	60 mm
6. Composite column section	
Section shape	Filled steel tube
Total depth	375 mm
Total width	375 mm
Fill material	Concrete
7.RCC Shear wall (M20 Grade)	
Thickness	200 mm
8.Steel plate shear wall (SPSW)	
Thickness	25 mm
Grade of steel	Fe 250

2.2 Plan Details

The plan details are kept same for all structures which are considered in this work, and are given below

Built up area: 20 m x 20 m
5 bays in each direction with width 4 m
Height of each storey: 4 m

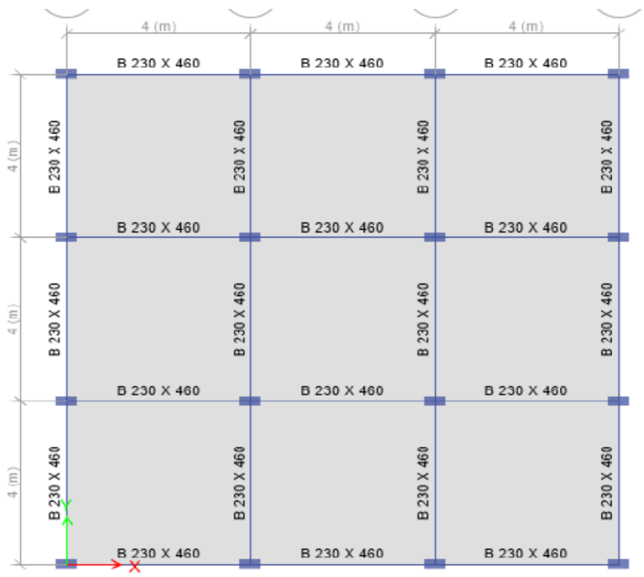

Fig -1: Plan and dimension of 20mx20m

3. MODELLING AND ANALYSIS

The modeling and analysis of G+2 and G+10 structures are done in ETABS V.15. The details of the models included in the study are given in Table 2

Table 2- Model Details

Building Type	Stories	Blast load (tonne)	Stand off Distance (km)
TYPE 1	G+2	0.1	0.01
TYPE 2	G+2	0.3	0.01
TYPE 3	G+2	0.1	0.03
TYPE 4	G+2	0.3	0.03
TYPE 5	G+10	0.1	0.01
TYPE 6	G+10	0.3	0.01
TYPE 7	G+10	0.1	0.03
TYPE 8	G+10	0.3	0.03

The type 1, type 2....type 8 buildings are modeled as RCC, steel and composite structures. In all cases the blast load is applied from the front face of the building. The building designations are given according to the type of structure and are shown in table 3

Table 3- Building designations and type of structure

Building Designation	Type of Structure
T1R	Type 1 RCC structure

T1S	Type 1 steel structure
T1C	Type 1 composite structure
T1RR	Type 1 RCC structure with RCC shear wall
T1RS	Type 1 RCC structure with SPSW
T1SR	Type 1 steel structure with RCC shear wall
T1SS	Type 1 steel structure with SPSW
T1CR	Type 1 composite structure with RCC shear wall
T1CS	Type 1 composite structure with SPSW

The blast load parameters were calculated as per the code IS 4991:1968 and the pressure diagrams are also created for each conditions. For the analysis time history functions are performed on each models, the maximum storey displacement in structures are analyzed for the discussion.

4. RESULTS AND DISCUSSIONS

All the selected building models with different blast loading conditions were analyzed for nonlinear dynamic behavior using commercial software ETABS (v15). The blast loads applied on the structures are calculated as per IS 4991:1968. The loads are calculated for G+2 and G+10 RCC, steel and composite structures at a standoff distance of 0.01 and 0.03km for 0.1 and 0.3 tonne charge of explosives
.

4.1 Maximum Storey Displacement Of G+2 Structures

The maximum storey displacements of all selected buildings were calculated on different conditions and are compared as G+2 and G+10 structures. In this section the maximum storey displacement of G+2 structures are discussed in detail.

4.1.1 Maximum storey displacement of G+2 RCC structures

The maximum storey displacements of the G+2 RCC structures were observed and are tabulated in Table 4. It is clear that the displacement is minimum in the case of type 3 RCC structures.

Table 4- Comparison of maximum storey displacement of G+2 RCC structures

BUILDING DESIGNATION	MAX STOREY DISPLACEMENT (mm)		
	GF	1F	RF
T1R	84.349	177.082	227.418
T2R	182.202	397.277	524.087
T3R	3.615	7.873	10.387
T4R	7.451	16.243	21.430

The displacement occurred on the roof floor of type 3 structure is only 2% of that of type 2 structures, where the maximum storey displacement is high in the case of type 2 RCC structures. The comparison of maximum storey displacement of G+2 RCC structures with SPSW and RCC shear walls are shown in Chart 1.

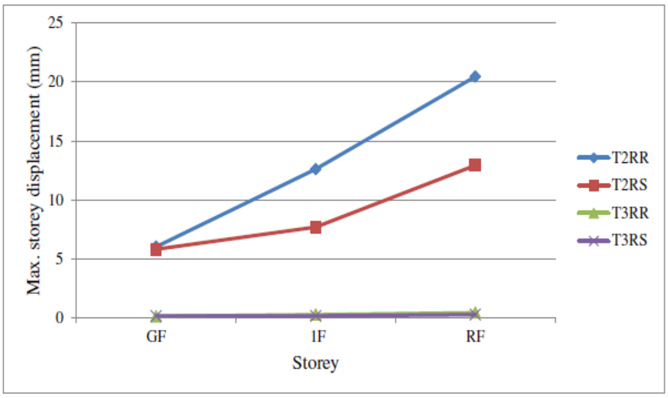

Chart 1: Max. Storey displacement Vs storey for type2 and type3 RCC structures with shear walls

It is clear that the displacement decreases while adding the steel plate shear wall. Here the addition of SPSW in type 3 structure helps to decrease the displacement by 30%. In the case of type 2 structures the SPSW reduces the displacement by 36% in comparison with the case of RCC shear wall.

4.1.2 Maximum storey displacement of G+2 steel structures

The maximum storey displacements of the G+2 steel structures were observed and are tabulated in Table 5. Here the storey displacement is maximum in the case of type 2 steel structures. The displacement occurred in type 3 steel structures are only about 2% of that occurring in type 2 steel structures. The variations of the storey displacement are shown graphically in Chart 2.

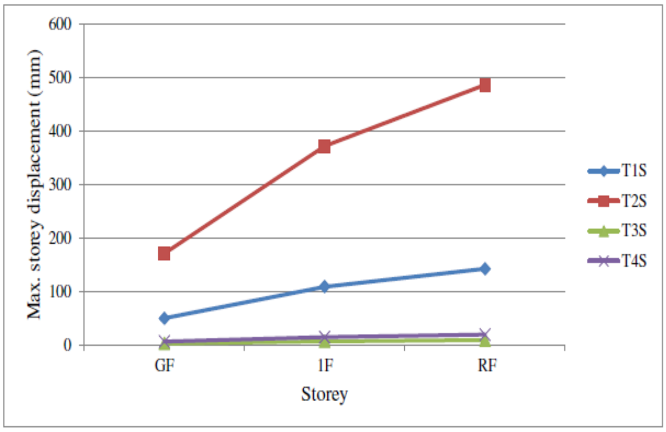

Chart 2: Max. Storey displacement Vs storey for G+2 steel structures

Due to the same standoff distance in type 3 and type 4 the displacements occurring are similar. From Chart 2 it is observed that type 2 steel structures are more weak under blast loading condition compared to others and the type 3 structures are stronger one.

The type 2 steel structures with RCC shear wall are highly affected due to the blast loading. When type 2 structures are added by SPSW, the displacements are get reduced by 35% than in RCC shear wall. The steel plate shear walls are more helpful in decreasing the maximum storey displacement occurring in a structure. These variations are graphically shown in Chart 3.

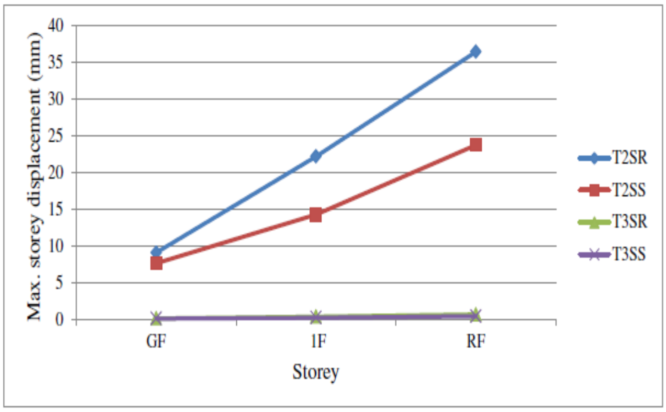

Chart 3: Max. Storey displacement Vs storey for type 2 and type 3 steel structures with shear walls

4.1.3 Maximum storey displacement of G+2 composite structures

The storey displacement is maximum in the case of type 2 composite structures. The displacement occurred in type 3 composite structures are only about 2% of that occurring in type 2 composite structures.

Table 5- Comparison of maximum storey displacement of G+2 composite structures

BUILDING DESIGNATION	MAX STOREY DISPLACEMENT (mm)		
	GF	1F	RF
T1C	34.281	81.179	111.058
T2C	116.534	275.969	377.518
T3C	2.320	5.485	7.504
T4C	4.777	11.311	15.474

The maximum storey displacement occurring in type 2 composite structure with steel plate shear wall are higher than all other structures. While applying RCC shear wall, the displacement occurring in structure get reduced to 85% of that occurring in the case with SPSW. It is clearly shown in Chart 4 as below.

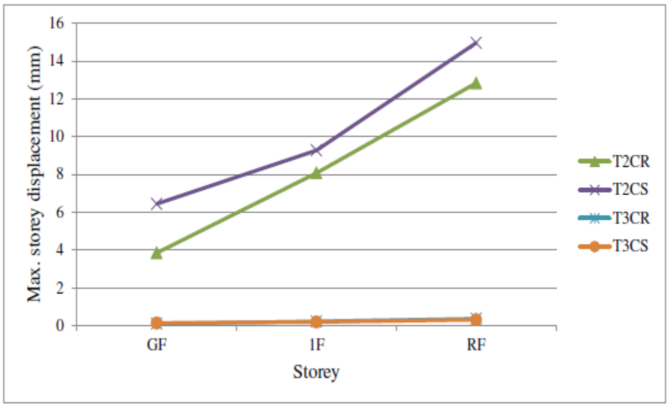

Chart 4: Max. Storey displacement Vs storey for type 2 and type 3 composite structures with shear walls

The values of maximum storey displacement of type 2 composite structures with SPSW and RCC shear walls are very high compared to type 3 structures, so the graphs representing type 3 structures are seems to be overlapping each other.

4.1.4 Maximum storey displacement of type 2 RCC, steel and composite structures with RCC shear wall

While comparing the type 2 RCC, steel and composite structures with shear walls, the type 2 composite structure with RCC shear wall is found to be better than others. The maximum storey displacement in type 2 composite structure with RCC shear wall is only 35% of that of steel structure and 62% of RCC structure. It is clear that type 2 composite structures with RCC shear wall experiences lower amount of displacement than the other two structures. The variation of maximum storey displacement of type 2 RCC, steel and composite structures with RCC shear wall is graphically shown in Chart 5.

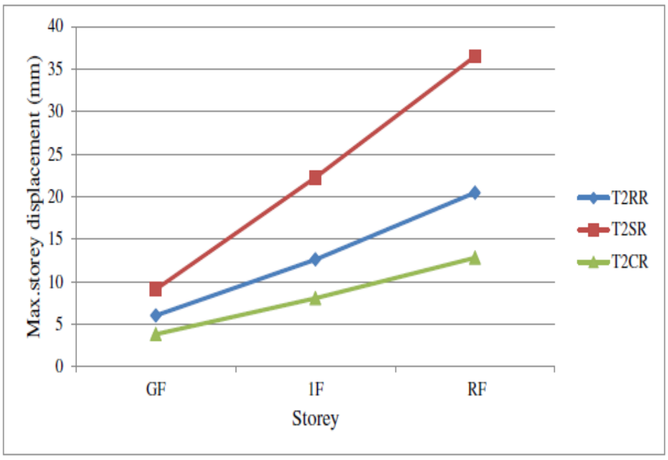

Chart 5: Max. Storey displacement Vs storey for type 2 RCC, steel and composite structures with RCC shear wall

4.2 Maximum Storey Displacement Of G+10 Structures

The following charts show the variation of maximum storey displacement of G+10 RCC, steel and composite structures with respect to the storey of each structure.

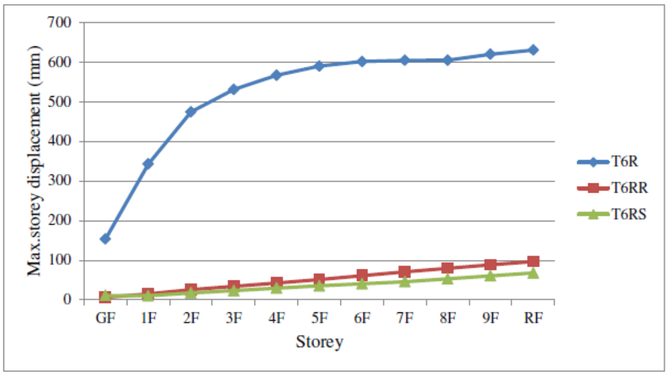

Chart 6: Max. Storey displacement Vs storey for G+10 RCC structures

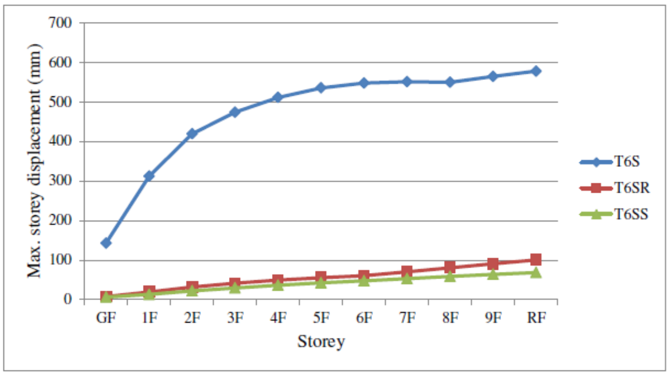

Chart 7: Max. Storey displacement Vs storey for G+10 steel structures

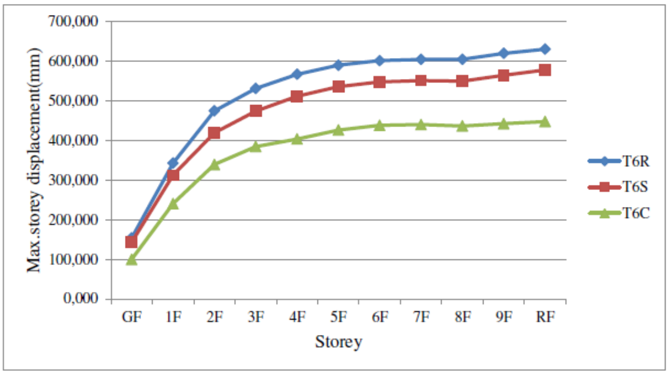

Chart 8: Max.storey displacement Vs storey for type 6 structures with RCC, steel and composite

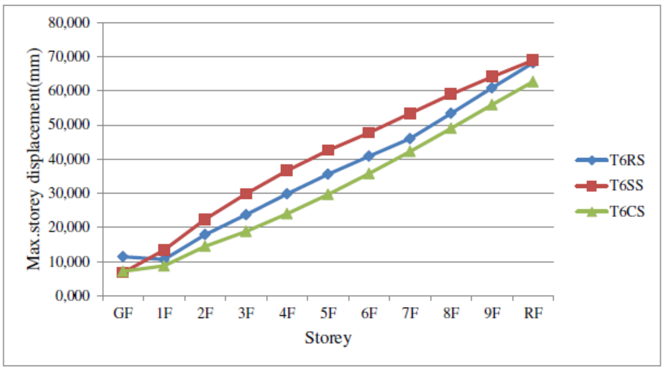

Chart 9: Max.storey displacement Vs storey for type 6 structures with SPSW

From Chart 6 to 9 we can observe that

- In the case of G+10 RCC structures type 6 shows the weak performance under blast loadings, since the maximum storey displacement is high in the case of roof floor of type 6 structures which are affected by 0.3 tonne charge at a standoff distance of 0.01 Km.
- When the type 6 RCC structures are added by RCC shear wall, then the displacement is get reduced to 15 % of the initial case where there is no shear wall. Also when type 6 RCC structure is added by SPSW, then the maximum storey displacement will get reduced to 10% of the initial condition.
- Among the G+10 RCC structures type 7 structures are better than other types. When type 7 structures are added by RCC shear wall, then the displacement is get reduced to 15%. Also when the type 7 RCC structures are added by SPSW then the displacement is get reduced to 10% of the initial condition where the shear wall is not considered.
- In the case of G+10 steel structures type 7 structures are better than other types. When type 7 steel structures are added by RCC shear wall, then the displacement is get reduced to 17%. Also when the type 7 steel structures are added by SPSW then the displacement is get reduced to 11% of the initial condition where the shear wall is not considered.
- In the case of G+10 steel structures type 6 shows the weak performance under blast loadings, since the maximum storey displacement is high in the case of roof floor of type 6 structures which are affected by 0.3 tonne charge at a standoff distance of 0.01 Km.
- When the type 6 composite structures are added by RCC shear wall, then the displacement is get reduced to 18 % of the initial case where there is no shear wall. Also when type 6 composite structures are added by SPSW, then the maximum storey

displacement will get reduced to 14% of the initial condition.

5. CONCLUSIONS

Based on the analyses of building models, the following conclusions are drawn.

- The G+10 structures are highly effected by the blast loads even though the standoff distance and the charge of explosions are the same as that of G+2 structures.
- Type 2 RCC structures are weak one and type 3 RCC structures are better under consideration of blast. The displacement occurred on the roof floor of type 3 structure is only 2% of that of type 2 structures.
- Type 3 composite structures with SPSW are better in the case of G+2 structures in resisting the blast loads.
- In the case of RCC structures with and without shear walls, the addition of RCC shear wall reduces the displacement by 96% and the addition of SPSW reduces the displacement by 98% than in the case without shear wall.
- The type 2 steel structures with RCC shear wall are highly affected due to the blast loads. When type 2 structures are added by SPSW, the displacements are get reduced by 35% than in RCC shear wall.
- The steel plate shear walls are more helpful in decreasing the maximum storey displacement occurring in a RCC structure and SPSW reduces the displacement by 98% than in the case without shear wall.
- The maximum storey displacement in type 2 composite structure with RCC shear wall is only 35% of that of steel structure and 62% of RCC structure.

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