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Comparative analysis of Steel concrete Composite Structure and RCC Structure under Accidental loading as per Unified Facilities Criteria

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ABSTRACT:

Accidental load resisting structures are completely different type of load than considered in the conventional design. They experience rapid moving shock wave which may exert greater pressures than those of pressure exerted by hurricane, but the peak intensity lasts for a very small duration. To design such structures which are capable of resisting intense but short duration loads , members and joints are permitted to deflect and strain much greater than the limit allowed for usual static loads .This permitted deflection is in plastic range of material hence large amount of energy are observed during this action, thus reducing the required design strength considerably below that required by conventional design which is within elastic range moreover under higher rates of loading the strength developed by the material increases with the rate of loading. There is a standard for analysis and design of blast loading in IS: 4991-1968 but there are limitations for this Indian Standard code covers the blast loads only above the ground and also it does not consider the blast effects of nuclear explosions and this code was proposed in 1968 which is far back to the present requirements hence we have used the analytical method which is prescribed by "Unified Facilities Criteria by Department of Défense of USA" this code was proposed in the year 2008. So, this procedure is considered as an advanced method when compared to IS code. Thus, by doing the proper study on above all aspects, there is a scope of study to resist blast loads using shear wall and steel concrete composite structures for a multi storey building through Etabs software.

Key words: Accidental Loading, Blast Loading, Surface Blast, Steel concrete composite Structure, RCC, Multi Storey Building, Shear wall, ETabs etc.

1. INTRODUCTION

Every structure is subjected to static or dynamic loading or a combination of both loadings. Structure designed to resist dynamic loading are subjected to complete different type of loading than that considered in conventional design. Dynamic loads on structures include study state service roads like live loads and machine loads and environment loads like wind load and earthquake load and accidental loads like impact and blast loads. In this work a discussion on this accidental load is carried on. Structures designed to resist accidental loads are subjected to complete different type of loads than that considered in conventional design. In case of accidental loads structures are hit with rapidly moving shock wave which may exert pressures many times greater than those experienced under greatest of hurricanes, however in accidental load phenomenon the peak intensity lasts for very small duration only. Thus, the response of each individual element is important. To design a structure capable of resisting these intense but short duration loads members and joints are allowed to deflect and strain much greater than allowed for usual static loads. This permitted deflection is well into plastic range of material. Accidental loads are transient and are with varying with intensity both with space and time. Elastoplastic approach in design is adopted for accidental loads and structure should be engineered to be as ductile as possible in this work we are going to work out we are going to analysis of a multi storey G+10 building using ETABS 2018 software. Blast resistance of a structure is improved by adopting either of the below modifications.

2. LITERATURE REVIEW

Literature pertaining to the present work may be divided into three major categories. The first category relates to the studies on blast loading and its effects on structures. The second one is concerned with the behaviour of steel concrete composite structure. The literature relating to these categories has been reviewed and the observations on the available literature are presented below

Ray Singh Meena in 2009 [1], focused on the design techniques for the loading on roof structures and the resistance of open web steel joists, a common roof component. Blast loads are dynamic, impulsive and non-simultaneous over the length of a roof. To design against explosions, a procedure has been developed to devise a uniform dynamic load on a roof that matches the response from blast loads. The objective of this research was to test and compare its results to the deflections from blast loads using FEM of analysis and to compare them to equivalent loading response. It is recommended that additional research is to be done on the prediction of blast pressures on roofs and on the development

B. M. Luccioni et al. [2] Department of Defence, other governmental office and public institutes. analysed an actual building which suffered terrorist attack. The analysis is compared with the photographs of real damage.

T. Ngo et al. [8] 2007 Analysis is done using AUTODYN software presented an overview of the effects of explosion on structures. An explanation of the nature of explosions and the mechanism of blast waves in free air is given. This study also introduces different methods to estimate blast loads and structural response. In the study the behaviour of concrete column under blast loads was made.

Ghani Razaqpur et al. [3] 2007, investigated the behaviour of reinforced concrete panels, or slabs, retrofitted with glass fibre reinforced polymer (GFRP) composite, and subjected to blast load eight 1000 x 1000 x 70 mm panels were made of 40 MPa concrete and reinforced with top and bottom steel meshes. Blast wave characteristics, including incident and reflected pressures and impulses, as well as panel central deflection and strain in steel and on concrete/FRP surfaces were measured.

Nitesh N. Moon [4] 2009 in his master’s degree thesis give the procedure for calculating the blast loads on the structures with or without openings and frame structures. He also made comparison between the normal strength column and high strength column which show that the critical impulse in case of the higher strength column is significantly higher.

Andrew Sorensen et al. [5] 2012 discussed various software used for blast analysis he also emphasized the use of software by personal having knowledge and experience.

Newmark and Hansen [6], This work illustrated the effect of nuclear blast on structures and recommended design procedures to withstand air blast. Simplified design charts were presented in this treatise, for the design of elasto-plastic structural elements subjected to a triangular pulse load. The nature and magnitude of load applied to various types of structures as a result of exposure to air blasts were discussed. Loading on the above ground and below ground structures were also dealt with separately.

3. METHODOLOGY

In this work mainly focused on steel concrete composite multi storey building which is analysed under the action of accidental loading especially blast loading using ETABS software. The blast loads are computed by using analytical methods which are prescribed in unified facilities criteria by department of defence of USA. This method is considered as an advancement to the method prescribed in IS:4991-1968. As IS:4991-1968 covers the criteria for design of structures for blast effects above the ground only and does not cover the design for blast effects of nuclear explosion.

3.1 Blast Load Calculation Graphs

The blast load parameters which are used at various stages of finding the final blast loads which is to be applied on the modelled structure are found out by using a series of graphs given below.

1. Free blast wave curves
2. Reflected pressure coefficient vs angle of incidence graph
3. Reflected scale impulse vs angle of incidence graph
4. Velocity of sound in reflected over pressure region vs peak incident over pressure graph
5. Peak incident pressure vs peak dynamic pressure, density of air behind the shock front and particle velocity

All the above graphs are taken from "STRUCTURES TO RESIST THE EFFECTS OF ACCIDENTAL EXPLOSIONS" by Unified Facilities Criteria (UFC), department of Defence USA in 2008.

3.2 Free Blast Wave Curves

This graph is read by using scaled distance (Z) and mapping the other properties with respect to the scaled distance (Z). From this graph we get the values of peak initial positive over pressure (Pso), wave front speed (U) and other scaled values like

- Scaled initial positive impulse $\frac{i_s}{W^{0.33}}$
- Scaled length of positive phase $\frac{t_o}{W^{0.33}}$
- Scaled value of wave arrival $\frac{t_A}{W^{0.33}}$

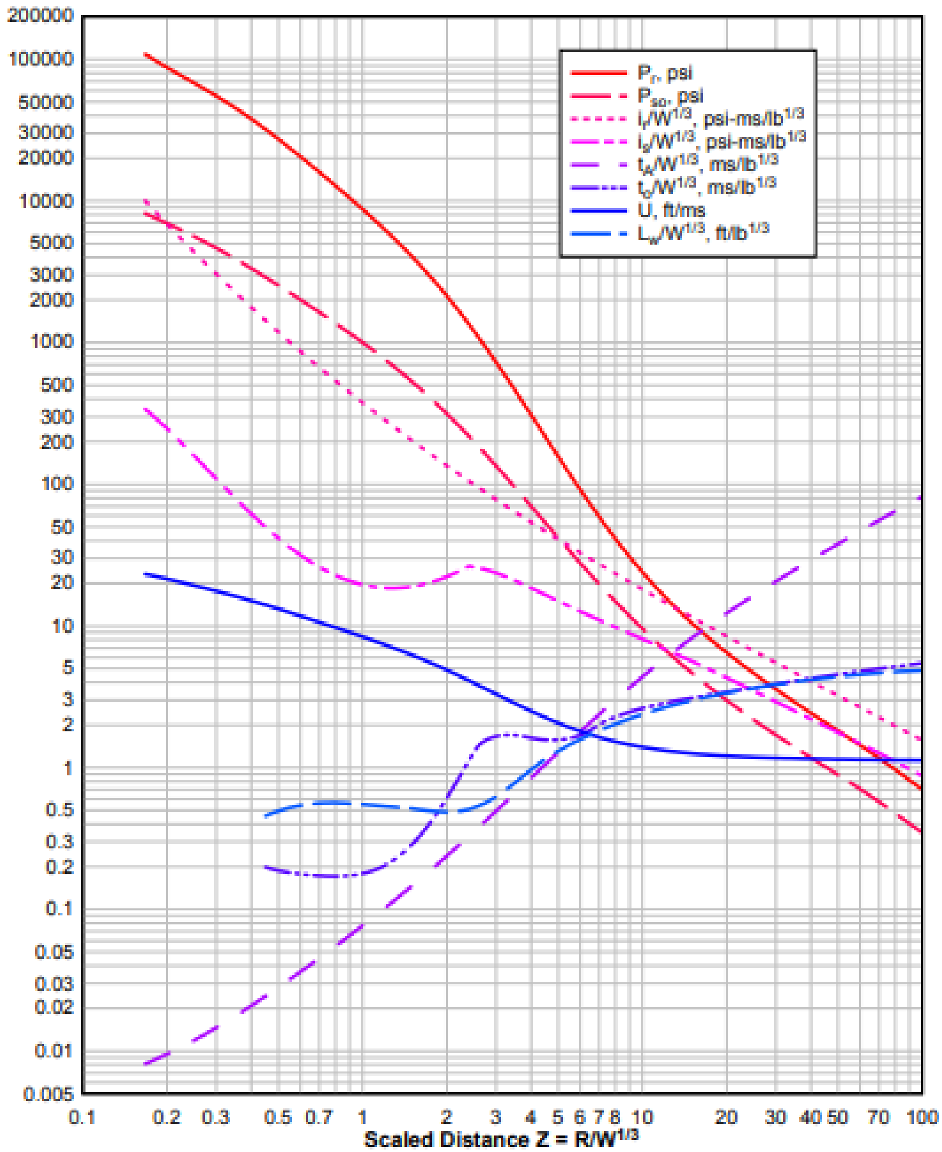


Fig 1 Free blast wave curves

3.3 Structural Modeling

In this study the comparative analysis is done on a multistorey building one having steel concrete composite beams and columns and other building of same dimensions but without steel concrete composite beams and columns. The modelling is done by using ETABS 2018. We have modelled a G+11 multistorey buildings with a plot size of 15 m X 15 m with 3 bays each of 5 m width and the base storey height is taken as 4.5 m which includes the foundation depth of 1.5 m and bottom storey of 3m and remaining all storey height is taken as 3m. These structures have a characteristic compressive strength of 40 N/mm^2 i.e M40 grade of concrete, In steel concrete composite structure we used ISWB 550 beams encased in rectangular cross section of M 40 grade concrete and the cross sectional dimensions of 900 mm X 600 mm is used. In columns I section of ISWB 500 is embedded in a M 40 grade concrete casing of 900 mm diameter. In RCC structure Fe 500 steel is used. In this model we have used rectangular cross section for beam and circular cross section for column because rectangular cross sections and I sections combinedly resist high bending moments due to vertical loads and columns of circular cross sections are used because of fact that tubular like sections is best for resisting lateral buckling. The slab of depth 200mm is used because in this analysis the application of live load and other normal loads are minimal, so the modelling of slabs is also given minimal importance. The foundations in this model are considered as fixed at all base joints. Shear wall is also modelled in order to minimize the lateral deflections. The detailed sectional properties of columns and beams used in both the structures i.e the structure with steel concrete composite construction and normal RCC structure are given below.

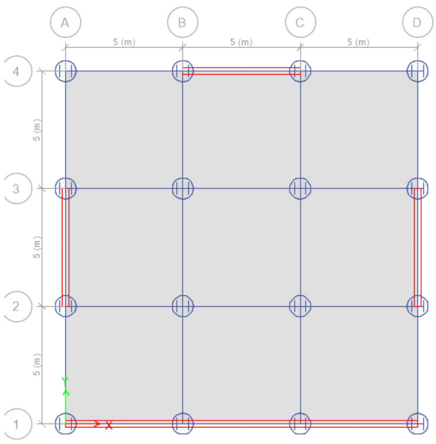


Fig. 2 Plan view of Steel concrete composite Structure

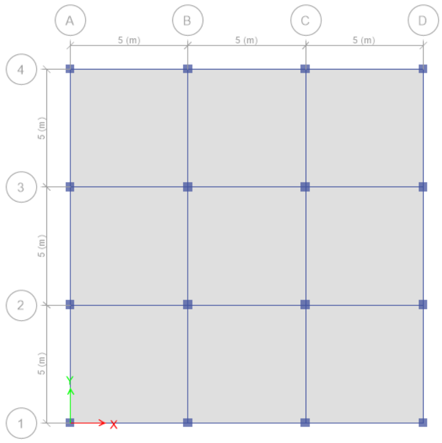


Fig. 3 Plan view of RCC structure

3.4 Accidental Load Calculation Using Analytical Method As Per UFC Guidelines

Step 1: Determining the weight of charge W

Take W = 2000kg TNT

Applying the factor of safety 1.2 we get W= 2400kg = 5291.09 lbs

Take charge distance R_G=50mts = 164.05ft

Step 2: Determining scaled charge distance $Z_G = \frac{R_G}{W^{0.33}} = \frac{164.05}{5291.09^{0.33}} = 9.41\frac{ft}{lb^{0.33}}$

Step 3: Determination of free blast wave parameters using fig 3.1

Using fig 3.1 and Z_G = 9.41$\frac{ft}{lb^{0.33}}$

We read the following below values

1) Peak initial reflected pressure P_r=29 psi
2) Peak initial positive over pressure P_{SO}=11psi
3) Wave front speed U=1.5$\frac{ft}{ms}$
4) Scaled initial positive impulse =$\frac{i_s}{W^{0.33}}$=9 psi-$\frac{ms}{lb^{0.33}}$
5) Scaled length of positive phase = $\frac{t_o}{W^{0.33}}$ = 2.5$\frac{ms}{lb^{0.33}}$
6) Scaled value of wave arrival =$\frac{t_a}{W^{0.33}}$ =2.1$\frac{ms}{lb^{0.33}}$

By multiplying the above scaled values with $W^{0.33}$ we will get the absolute values, the absolute values are as follows

1) Absolute initial positive impulse = i_s = 156.86 psi-ms
2) Absolute length of positive phase = t_o =43.56ms
3) Absolute value of wave arrival = t_a=36.593 ms

Step 4: Determining the positive peak refracted values

1) Finding the different values of " $\propto$ " at different points on building where the load acts by using the below formula

$$\propto = \frac{charge\ to\ wall\ center\ ground\ distance}{charge\ to\ wall\ normal\ distance}$$

Now by reading the " $\propto$ " values at different points of the building from we get the following table

Table 1. $\propto$ values for exterior beam column joints i.e A, D Sections

S.No	Charge to wall Centre ground distance	Charge to wall normal distance	$\propto = \frac{charge\ to\ wall\ center\ ground\ distance}{charge\ to\ wall\ normal\ distance}$
1	50.55	50	1.011
2	50.67	50	1.0134
3	51.44	50	1.0288
4	52.07	50	1.0414
5	52.87	50	1.0574
6	53.81	50	1.0762
7	54.94	50	1.0988
8	55.09	50	1.1018
9	56.04	50	1.1208
10	57.55	50	1.151
11	59.04	50	1.1808
12	61.2	50	1.224

Table 2. ∝ values for exterior beam column joints i.e B, C Sections

S.No	Charge to wall Centre ground distance	Charge to wall normal distance	$\propto = \frac{charge\ to\ wall\ center\ ground\ distance}{charge\ to\ wall\ normal\ distance}$
1	50.41	50	1.0082
2	50.48	50	1.0096
3	50.68	50	1.0136
4	51.27	50	1.0254
5	51.67	50	1.0334
6	52.06	50	1.0412
7	53.81	50	1.0762
8	54.65	50	1.093
9	55.29	50	1.1058
10	56.71	50	1.1342
11	58.03	50	1.1606
12	59.16	50	1.1832

2) By reading the " ∝ " values in Fig 3.2 we get the "$C_{r\propto}$" values and by considering the maximum "$C_{r\propto}$" value from maximum " ∝ " we get

   $C_{r\propto}$=2.3 (MAXIMUM VALUE) for A, D sections

   $C_{r\propto}$=2.2 (MAXIMUM VALUE) for B, C sections
3) Now we take the absolute maximum " $C_{r\propto}$" as 2.3
4) Finding positive peak refracted value

   $P_{r\propto} = C_{r\propto} \times P_{SO}$ =2.3× 11 =25.3 psi
5) Finding the scaled positive refractive index

   From fig 3.3 we read the value of $\frac{i_{r\alpha}}{W^{0.33}}$ as 17 (scaled value)

By multiplying the scaled value with $w^{0.33}$ we get absolute value =159.9 psi-ms

Step 5: Determining the positive phase of the load on the face exposed to the blast.

a) Determine the speed of sound in the area of reflected over pressure C_r from Fig 3.4, for the given peak over pressure P_{s0}

   $C_r = 1.32 \frac{ft}{ms}$

b) Calculate the clearing time $t_c = \frac{4S}{C_R\,(1+R\ )}$ =18.58ms

c) Calculate the fictious length of positive phase t_{of}

$$t_{of} = \frac{2i_s}{p_{so}} = 28.52\text{ms}$$

d) Determine the peak dynamic pressure from fig 3.5

$$q_o = 2.2\ psi$$

e) Determine p_{so} +(C_D .q_0) = 11+(2.2× 1)=13.2psi

From drag coefficient table

Table 3 Drag coefficient value

Loaded surface	C_D
Front	0,8 ÷ 1,6
Rear	0,25 ÷ 0,5
Side and roof (depending pressure, kN/m^2)	
0 ÷ 172	–0,4
172 ÷ 345	–0,3
345 ÷ 896	–0,2

f) Calculate the fictious length t_{rf} of the refracted pressure

$$t_{rf} = \frac{2i_s}{p_{ra}} = \frac{2\times 159.97}{25.3} = 12.64$$

Step 6: Determining the negative loading phase on the face where blast load acts

a) Determine the $P_{r\alpha}^{-}$ and $\frac{i_{r\propto}^{-}}{W^{0.33}}$ from fig 3.1

$$P_{r\alpha}^{-} = 2.3\times 29 = 66.7 \text{ psi}$$

b) Calculate the fictious duration of the negative refracted pressure

$$t_{r\propto}^{-} = \frac{2i_{r\propto}^{-}}{p_{r\propto}} = 22.52 \text{ ms}$$

c) Calculate the negative phase time increase by multiplying the t_{rf} with 0.25

=0.25×12.64 = 3.16ms

d) Define the pressure time history curve for the negative phase of the load.

Step 7: Calculation of final point load to be applied

$$P_{r\propto} = 25.3 \text{ psi} = 174.437\ \frac{KN}{m^2}$$

Now final force = $P_{r\propto}$ × Area of influence = 174.437× 7.496 = 1307 KN

This is the final force to be applied on multistorey buildings.

CHAPTER 4. ANALYSIS AND REPORTS

The above structures which are modelled as described in chapter III are analysed using E Tabs-2018 software. For these structures, the load applied load is 1307KN as a point load at every beam column joint which are facing the blast wave. as calculated in the above chapter. Here we have taken 1307KN at all points though we got different load values at different points because 1307KN is the highest value among all those and thus structure is analysed on a safer side.

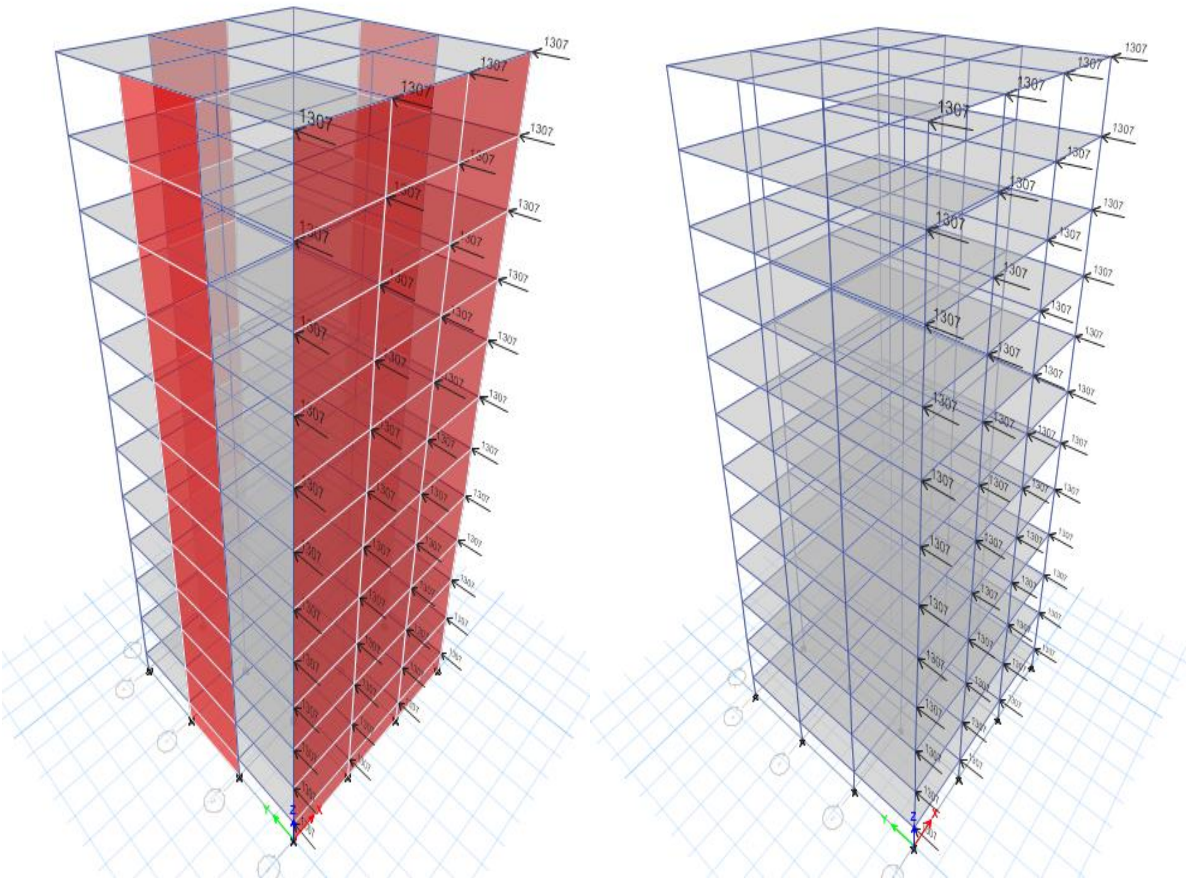


Fig. 4. Blast load application on beam column joints of Steel concrete composite structure and RCC structure.

4.2 Load Combinations

As per IS-4991 – 1968 of 11.1 & 11.2 of page no.33 wind or earthquake forces shall not be assumed to occur simultaneously with blast effects. Effects of temperature and shrinkage shall also be neglected. No live load shall be considered at the time of blast. Hence only the combination of dead load and blast load is taken into consideration. In these structures we have used P-M2-M3 type of analysis for column and M3 analysis for beams.

CHAPTER 5. RESULTS AND DISCUSSION

From the above analytical procedure, we have found out the shear force, bending moment, base reactions and deflections for both the structures that is Structure with steel concrete composite sections and RCC sections. The above obtained results are shown in the form of Shear force diagram (SFD), Bending moment Diagram (BMD), Base reactions (BR) and deflections at each beam column joint at each storey level of the structure.

5.1 Shear Force

Shear force is a force applied perpendicular to a surface, in opposition to an offset force acting in the opposite direction. This results in a shear strain. In simple terms, one part of the surface is pushed in one direction, while another part of the surface is pushed in the opposite direction. Following are the shear force diagrams which we have obtained after analysing the structures that is Structure with steel concrete composite sections and RCC sections under a blast load of 1307 KN which is obtained from analytical calculations.

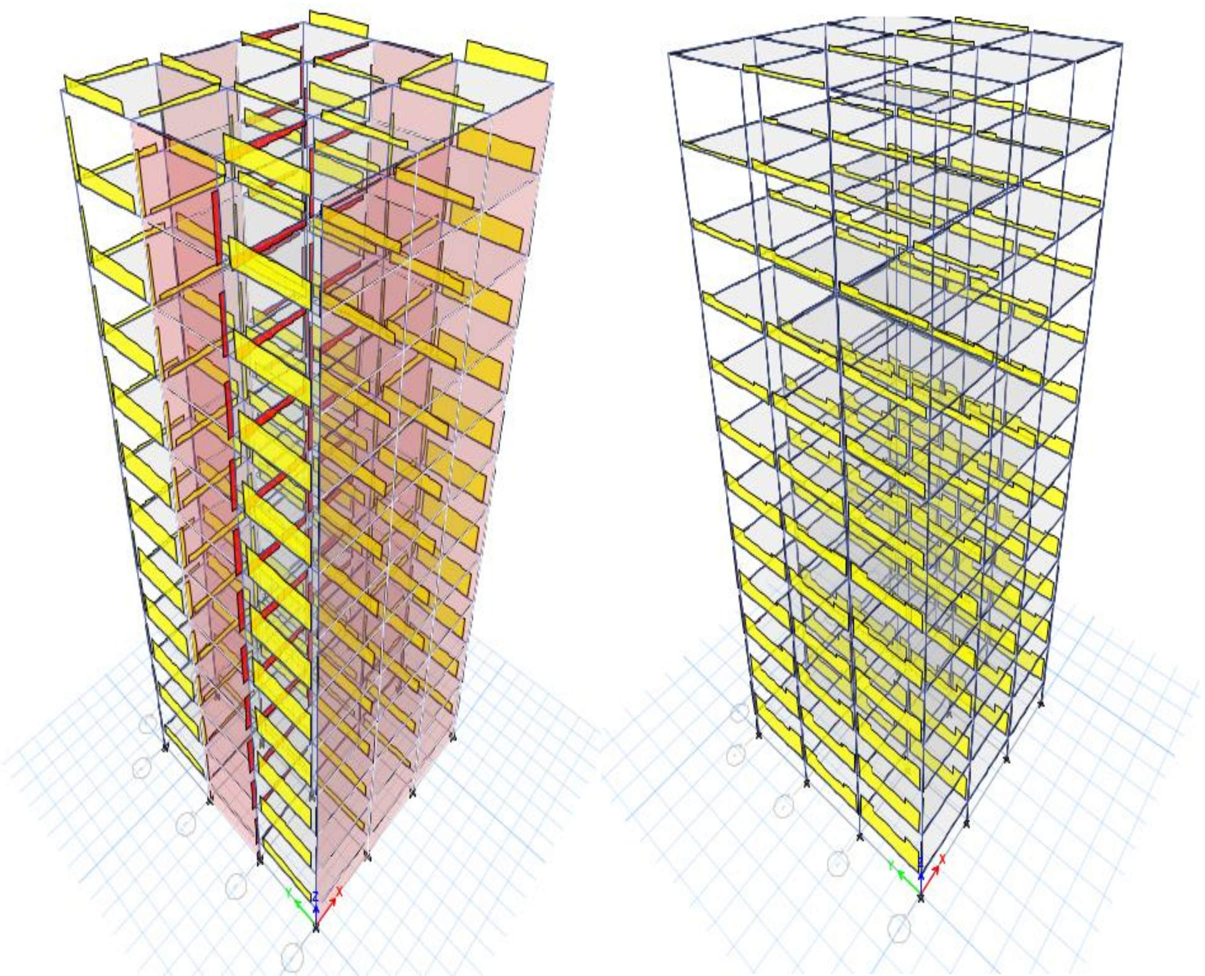


Fig 5. Shear force diagram of Steel concrete composite structure and RCC structure.

5.2 Bending Moment

A bending moment (BM) is a measure of the bending effect that can occur when an external force (or moment) is applied to a structural element. This concept is important in structural engineering as it is can be used to calculate where, and how much bending may occur when forces are applied. Following are the bending moment diagrams which we have obtained after analysing the structures that is Structure with steel concrete composite sections and RCC sections under a blast load of 1307 KN which is obtained from analytical calculations.

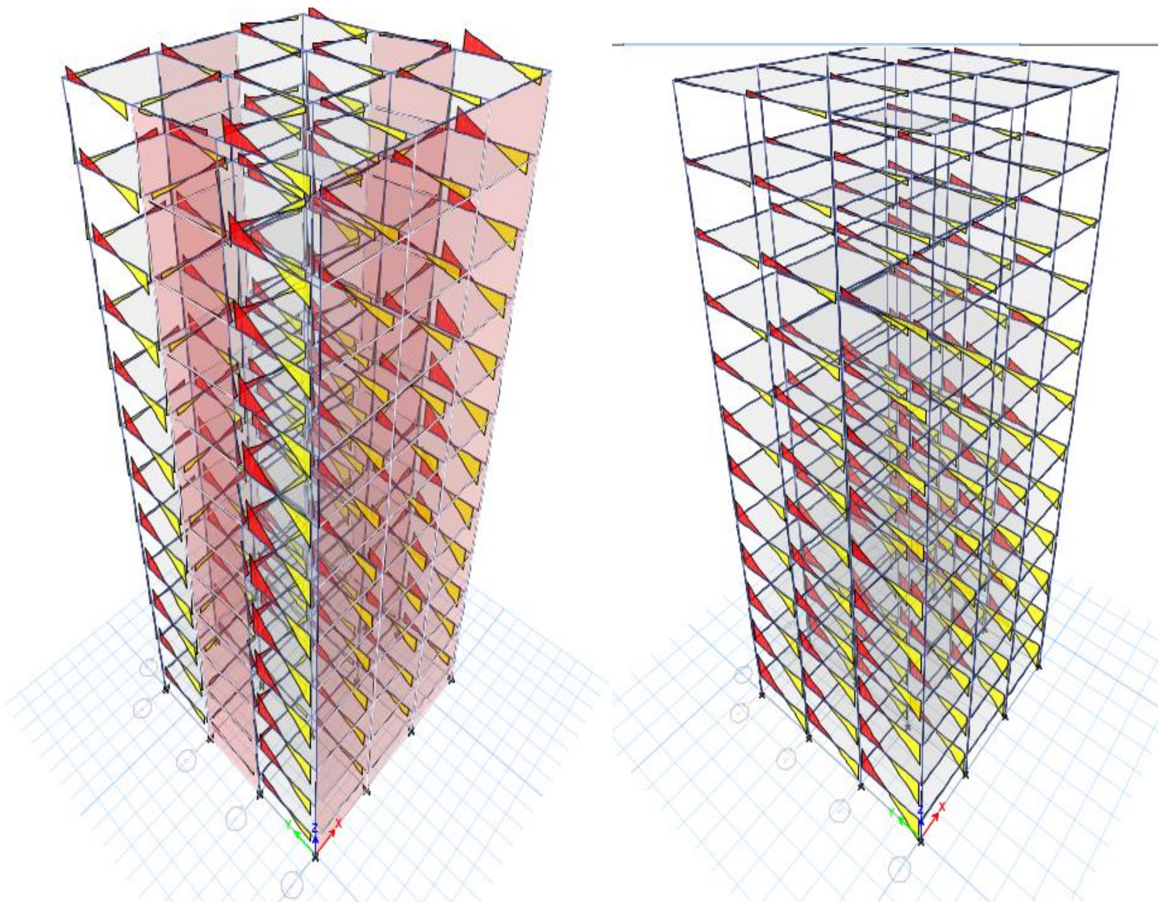


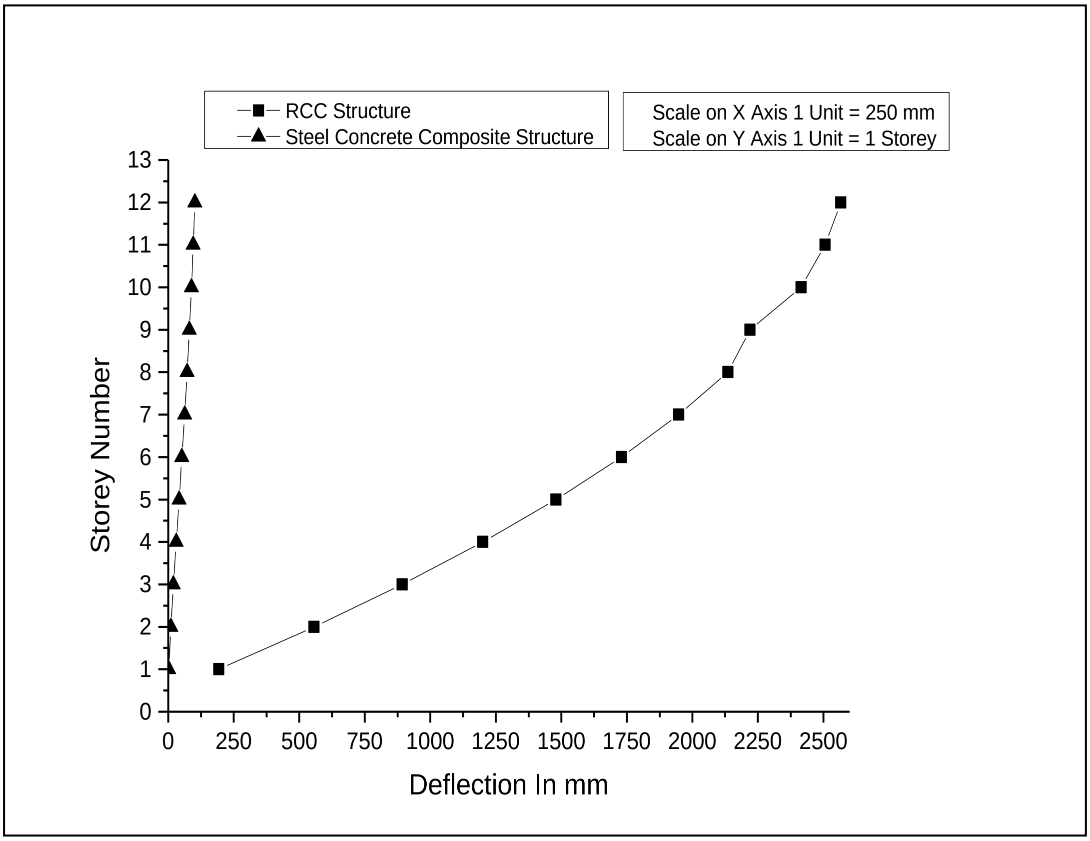
Fig. 6. Bending moment diagram of Steel concrete composite structure and RCC structure.

5.3 Deflections:

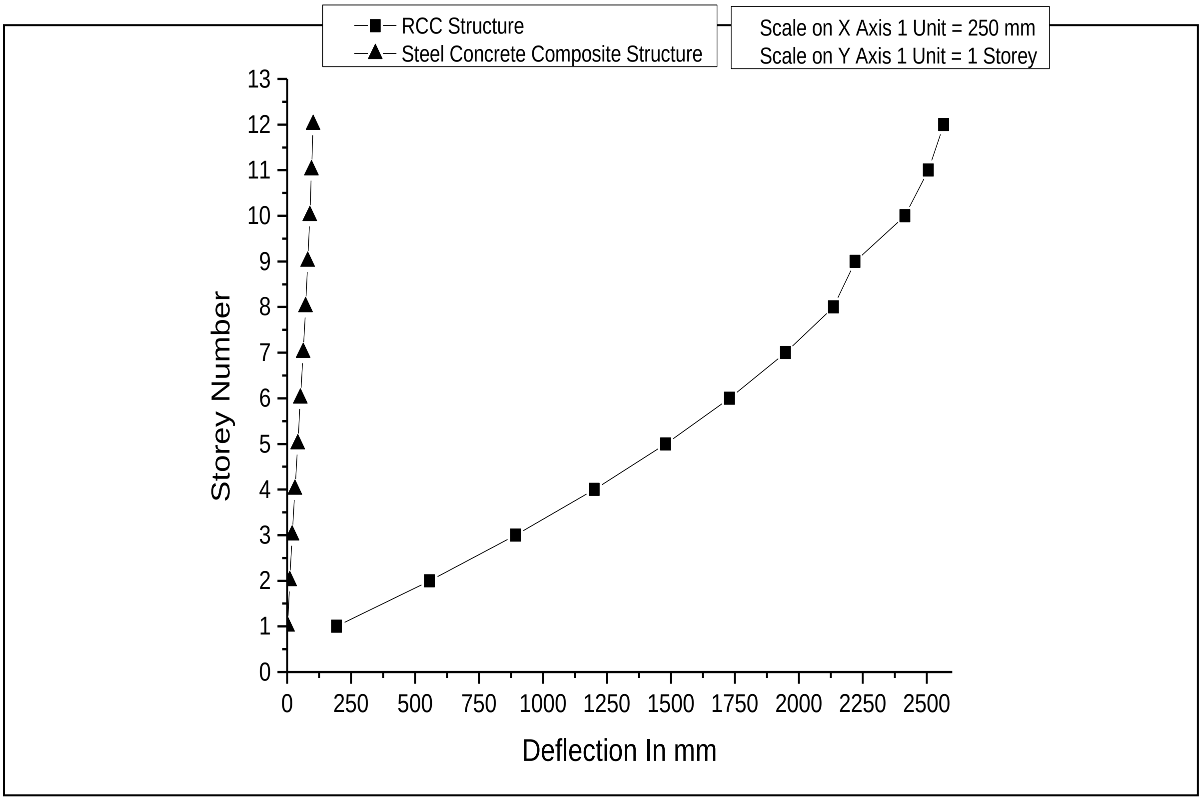
The deflections are the strain values obtained by comparing the position of deflected shape after applying load to the original position without applying the load. In this analysis the effect of blast loads on structures is compared based on the deflections observed in Y direction of building that is in the direction where the blast load is applied. Due to symmetry the A,D sections and B,C sections experience equal deflections and these deflections are presented in the table 4

Table 4. Deflection values for RCC & Composite structure.

Storey	RCC Structure		Composite Structure	
	B,C sections	A,D Sections	B,C sections	A,D Sections
1	193.000	193.237	1.946	2.073
2	556.085	556.248	10.279	10.14
3	892.410	892.668	20.036	19.841
4	1200.687	1200.945	30.641	30.468
5	1479.925	1480.184	41.562	41.434
6	1729.279	1729.538	52.351	52.21
7	1829.112	1948.287	62.562	62.474
8	1947.881	2135.836	72.082	72.007
9	2135.429	2219.709	80.751	80.683
10	2415.292	2415.553	88.537	88.465
11	2506.853	2507.105	95.471	95.442
12	2566.864	2567.14	101.250	101.315



Graph 1. Comparative graph of AD sections of Steel Concrete Composite Structure and RCC Struct
ure



Graph 2. Comparative graph of BC sections of Steel Concrete Composite Structure and RCC Structure

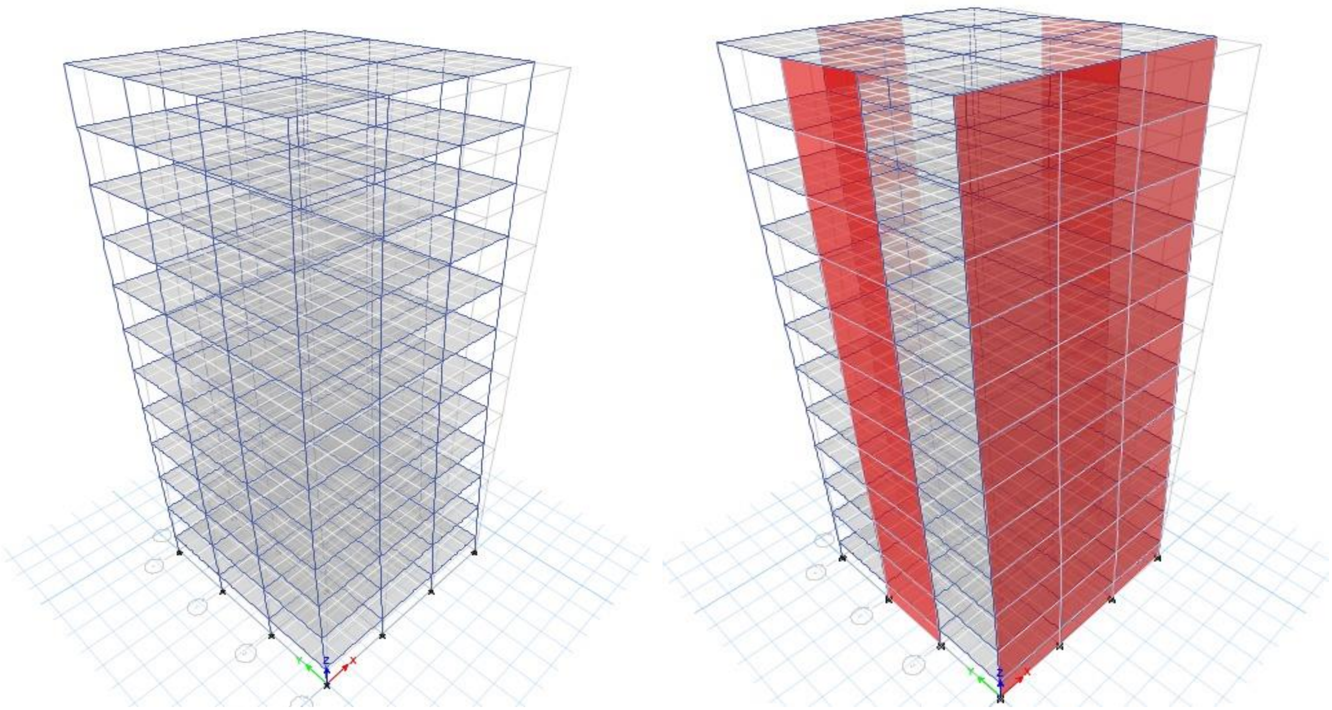


Fig.7 Deflected shape of Steel concrete composite structure and RCC structure after application of blast load.

CHAPTER 6. CONCLUSIONS

- In this work we have modelled two structures one with steel concrete composite sections and another with RCC sections. These two structures are analysed under a blast load of 1307KN at beam column joints on front facade of the structure.
- This blast load is calculated using analytical methods which are prescribed by Department of Défense USA in "Unified Facilities Criteria – 2008 (UFC)".
- In the case of RCC structure maximum deflection is 2567.140mm and the maximum deflection in case of steel concrete composite structure with 101.315mm.
- From the analysis it is observed that 96.05% deflections are reduced by using the structure with steel concrete composite sections with shear walls when compared to normal RCC structures with M40 grade concrete for both structures.
- As per IS 875 part 3 the maximum permissible deflection of structure is 0.004 times the height of the building which is 132 mm for the analysed structures which is satisfied in case of Steel concrete composite structures with shear wall.

Thus, we can conclude that by using steel concrete composite sections with shear wall the deflections of a multi storey building are greatly controlled under surface blast loading.

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