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DESIGN OF A MULTI-STORIED BUILDING RESISTANT TO TNT EXPLOSIVES

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Abstract

Many nations have become victims of terrorism at a grand scale. Bombs have exploded in and around buildings in many countries causing civilian causalities and structural damage. As a result, such events have generated considerable concern over the ability of countries to protect buildings and their occupants from the continued threat of bombings. The issue of the structural integrity of existing buildings is now a burning one.

This paper gives a basic emphasis on the blast response of a structure subjected to large TNT explosive. In this research work a FEM model was developed by placing a blast target at a distance of 30m away from the structure. The impact of blast with varying heights of the structure is measured with respect to coordinate axes. In distinction to the above 'PRO' Reflected over pressure has also been estimated for a structure subjected to blast loads. As a safety measure, the optimum thickness of shear wall has been recommended

Keywords: Blast loads, PRO, retrofitting measure, shear wall.

1. **Introduction:**

In the recent years to increase the awareness among the people about the possibilities of terrorist attacks all over the world many countries and the organizations are in collaboration to work and construct the magnificent architectural benchmarks in every country with high level of security methods. The facilities of the constructions are included to withstand the severe blast offloads because of the explosions. After the World War II many research and development organizations continued to make study on testing the reinforced concrete structures which can withstand the blast. There were many extensive research carried out in all countries to test develop and design the blast resistance concrete structures. One such differential structured developed by the Massachusetts Institute of technology was called as TM 5- 1300.

In the early 1980 with the increase in the terrorist bomb attacks many government organizations including high level professionals decided to launch the special structure for the buildings like government buildings and many magnificent iconic structures to be designed to resist the blast. Usually the government and other public organization increased and changed the durability and the design of the pre-existing building structures and modified the security measures to make the future buildings safe from attack and specially because of the explosive blasts the building may lose the intensity and leads to the collapse which in turn affects the effort of the construction not only but also there is a severe threat to the common man life.

In this research project we have analyzed the amount of threat posed by these explosion to the life of the buildings and we have accordingly studied the standard measures that has to be taken care of to construct buildings and specially the test using the etabs software was performed to check the amount of energy released when the explosion takes place near the building which included the trinitrotoluene TNT.

2. **Aims and objectives;**

The purpose of this research is to investigate and analyze the different dynamic models will produce accuracy and efficiency for the building structures which are affected by the blasts or due to the any external explosion. The method which is applied to study this research is basically on making the use of different static deflection nodes for a particular building structure which will be subjected to the kinematic boundary conditions and by using the software etabs we can dynamically study the system.

Some of the questions answered in this research work are:

- How should be the behavior of the building space after the explosion?

- Does the result of the analysis will affect the building structure with the main difference between the time of the blast and parts of the building?
- What should be the difference development that needs to be carried out in the building structure in this blast analysis after analyzing the results?

3. Scope of the project:

The main scope of the project is to investigate they approximate specifications of the building and to analyze define it element structured which actually resembles the original structure of the building with respect to the cross sectional area and moment of inertia on the each floor. The structure will be investigated as per the surrounding structures and by using the 2 dimensional beam elements. The basic equation which is introduced here to minimize the vibrations and neglect the modes in this structural building which is produced after the explosion. Explosion is taking place when there is a basic ignition in the trinitrotoluene or any other type of explosions for example typically the gas explosion. The effect of the debris and the fragmentation will also account in the structural integrity of the building and are dependent on the blast waves. The impulsive force which is produced by the explosion on the model at four different conditions are studied and simplified for the 2D model. Normally produced pressure which is also called as pressure load will also affect the change in the incident angle due to the selected reference building and that can be neglected. The negative effect of the blast wave load is also studied and neglected for some extent.

4. Methodology:

In the chapter of introduction we have already discussed about the basics of the blasts explosions and how the load acts on the building structure. The explosion can be stated as the spontaneous chemical reaction in which the solids or any other gases will combine and the expansions indeed products occur. We can divide the explosion into many types basically there are two types of the explosion they are the detonation and deflagration. The deflagration is a type of explosion in which the spontaneous combustion takes place due to the heat transfer or we can say that some hot burning gases will ignite and heats up the materials present in the area. And in this research the spontaneous combustion took place with the duration of small microseconds which is known as detonation and this type of explosion occurred with the usage of trinitrotoluene (TNT).

Whenever the explosion occurs it will produce the high temperatures and different levels of pressures because of the creation of hot gases. Basically the expansion continues to behave as a wave type in the propagation and acquires the medium in which it is traveling and forms a spiritual and shock front similar to the blast wave with the hot gases. Generally the blast wave produced increases with the increase in the pressure levels and drops to the normal atmospheric pressures. When blast waves travel further away from the area of explosion within a short duration of time below the atmospheric pressure there will be decrease in the intensity of energy.

Whenever the blast waves are produced in the building structure the basic principle is to neglect the negative phase for the longer duration and minimum intensity. The phase in which the positive waves are produced have much greater intensity of energy in the very short duration of time because of the structural damage that is produced when the integrity of the structure is subjected to the explosion. to model this blast wave loads in the research we have neglected the negative phase and included the highest magnitude of pressure well worthy atmospheric pressure and this over pressured will occur at specified time and also reduces as the time progresses. In this research when the building structure is designed and analyzed which is affected by this blast wave the pressure is idealized and or triangular impulsive phase was created with high pressure and the duration.

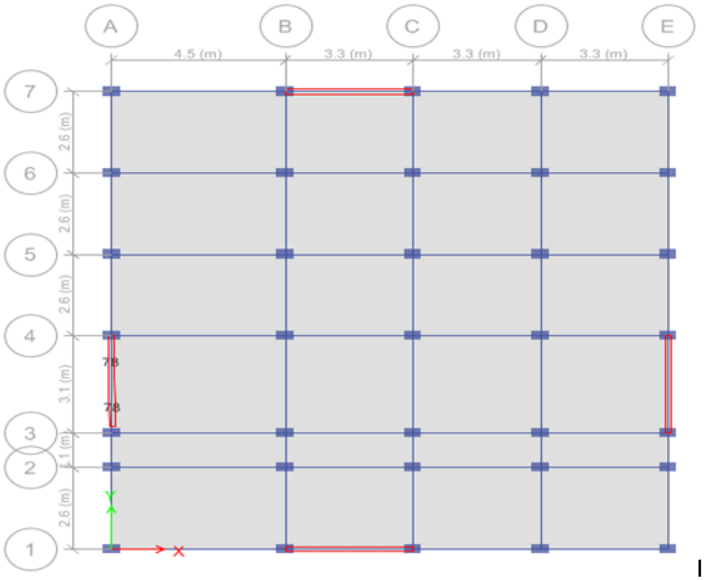

Figure 1. Plan of the multi storey building

The standoff distance and the weight of the bomb is also considered importantly in this explosion test and the weight of the bomb is taken to be W and the standoff distance is denoted as R. The distance between the actual explosion or detonation and the target point is called as the standoff distance and the range of this detonation takes place whenever the terrorist attacks at the various points of this building structure.

4.1Scaling for the blast waves:

The standoff distance which is denoted as R taken from the point of detonation as already mentioned and one of the important parameter that has to be considered in this explosion is the blast loading. The highest pressure value and the speed of the blast waves are quickly generated whenever the standoff distance increases and the characteristics of the explosion is specifically mentioned which are affected by this distance of attack and it is taken into consideration and developed in this model.

The effect prodced by the blasts is also noted down and the scaling laws are introduced to charge with the different number of bomb weights and distances with same scaled distance Z. These experimental selections and theoretical observations helped us to carry out the comparison between the different blasts at different distances.

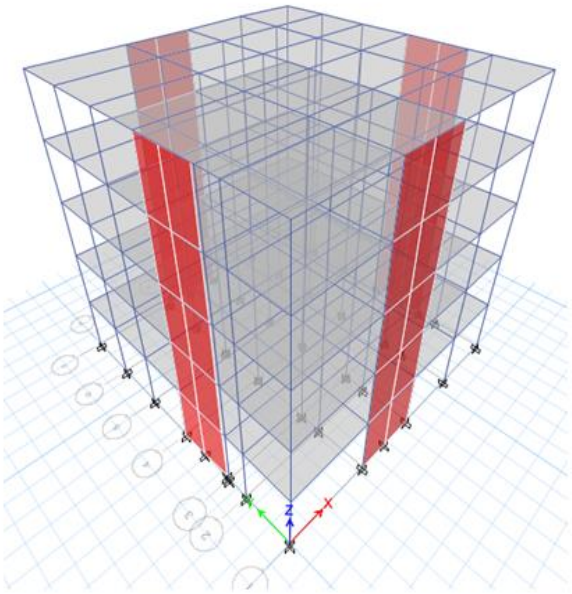

Figure 2. 3D view of the multi storey building

The effect of the blast is determined by the relative distance and the total energy produced within the ambient pressure and the ambient pressure will be directly proportional to the atmospheric pressure and can be expressed in terms of input of energies of the explosion and the weight which is almost same as the trinitrotoluene. Theoretical calculations included the distance which is also called as the scaling distance produced with the help of Hopkinson law of scaling. Generally the scaling distance is also affected by the weight of the TNT. The scaling is basically dependent upon the surrounding environment in which the free explosion takes place and also accounts for the total amount of energy released in the specific volume in which the blast waves propagate at expanded distance.

The volume of the surrounding is taken to be as cubical in the 2D model and for the 1D model the cylindrical and the linear distances are considered in which the expansion in the cylindrical surface is always proportional to the linear surface of the model.

In this section of methodology we are using two methods to analyze the basic structure of the building how it is affected by the loadings when the explosion takes place on 2 dimensional structural models. The methods that are used for this analysis are based upon the duration of the impulse force and the reduction of the system which is called as Rayleigh Ritz method. By using the software tool called etabs we have computed the reserves for a full scale structural building model and this model is constructed through the same software and analyzed to get the results up on the assumptions made. To make and broader analysis on how these structural building is badly affected by the blast wave forces the two dimensional finite element analysis was created for this model and under several different loading cases the model is tested and each case is analyzed according to the Rayleigh Ritz method. The variations in the external scenarios of the explosion and four other different cases are studied and simulated and the results are noted down.

4.2 Modeling set up:

Sectional properties**:**

Beam 300x300mm

Column 300x450mm

Shear wall 160mm

Rigid diaphragm

Distance from blast source and the target point

Coordinates of point of interest			Distance between source and target	SLAB
30	3	0	30	SLAB-1
30	3	3.7	30.23	
30	3	9.4	31.43	
30	6	0	30.15	SLAB-2
30	6	3.7	30.38	
30	6	9.4	31.58	
30	9	0	30.59	SLAB-3
30	9	3.7	30.82	
30	9	9.4	32	
30	12	0	31.32	SLAB-4
30	12	3.7	32.54	
30	12	9.4	32.7	
30	15	0	32.31	SLAB-5
30	15	3.7	32.52	
30	15	9.4	33.65	

The basic reference for the structure of the building is constructed with five story which is having 8 meters of long sides and the total building height of 20 meters is constructed and also the height of the story of the building Is mentioned as 3 meters. The three dimensional structural model of the building is shown in the figure and it is basically referred with the multi degree of freedom in which the first degree of freedom is given for every Ritz vector. The structural building model is taken into consideration to support the steel pillars which will also include some concrete slabs and the selection of this structure is basically dependent upon the model simplicity and supporting structure of the multi Storey building. The structure is built with the considerations of all six degrees of freedom in which the movement is subjected to horizontal and vertical directions with only one degree of freedom for the rotation for every node which is considered in this model. So there are in total 180 degrees of freedom in the selected simulated model with zero damping and the analysis is carried out in the undamped system for the equations of motion.

4.3 Stiffness and mass analysis:

The 3D structural model of the building which is constructed by using the etabs command are taken into considerations and similarly the stiffness of the building is analyzed by considering the symmetrical type of stiffness matrix in which the degrees of freedom will be in the total size. The beam of the 3D structural model is taken as beam 3D command Which in turn creates a systematic mass matrix by negligible influence of the inertia of rotation. The mass of this structure in the rotational formats are taken in so considerations with the degrees of freedom which are in turn equal to the zero. The matrix which is constructed and arranged in the symmetric form is specified with the diagonal mass matrix which can be used in the normal approach when we are analyzing the building structure dynamics. The mass matrix which is constructed by taking the sum of the entire weight of the other structural elements off the building and separately distributed in both vertical and horizontal directions. The degree of rotation and the degree of freedom is taken to be with the value of 1/1000. The basic equations for the system are solved and neglected the smaller numerical errors, to solve the system of equations of the eigenmodes and the frequencies of eigenvalues we calculate and solve the Eigen value problems.

4.4Blast load distribution:

By considering the reference of the structure of the building which is already subjected to the load because of the explosion we can say about the blast load distribution. The impulsive force which is created on model or the blast wave which is modeled on the sideways of the structure of the buildings is assumed and the six different points on the structure are subjected to the forces. In this distribution of loads we will also consider the distribution of the pressure which is acting on the structure of the building as shown in the figure and because of the arrival time in the sideways of the building the explosion is assumed to be happened in the near elevated ground area which is at the distance height of H. The height which is considered in this section is also called as the detonation height which is approximately taken to be as 1.8 meters above the ground level. The distance from the area of the

detonation to the structural building is calculated and the storey height is also taken into consideration with the standoff distance. These distances are calculated which are very helpful in the analysis of the building structure in accordance with the law of scaling which is presented in the previous chapter. The parameters that are considered in this blast analysis are usually derived using the diagrams under parameters such as the arrival time the duration Andy positive phase of the scale are presented and they are multiplied with the different factors in all the cases.

4.5 Cases of explosion:

In the analysis of the explosion situations which are very common when there are some terror attacks in the buildings and when the buildings are very close to the ground areas we will consider different types of loading scenarios with the variable standoff distances and here in this case we are using the explosives which are equivalent to the trinitrotoluene and weighted as W. The variable loading conditions are taken in the four steps and are selected based upon the accuracy of the results obtained from the various large and very small explosive elements which are weighed with their respective difference in this standoff distances from the targeted area with variations in the times of arrivals and the pressures.

4.6 Case 1:

Force model

In this force model two withstand the load in the constructed area of the building we will consider a triangular load which is acting with the load factor F , And with the time variations T. Upon the analysis and the simplifications we can say that the forces acting on the building structure consist of a positive phase with the time dependent vector which is created by using the function in the Etabs and witty increase in value of the pressure and the time duration in these explosion scenarios.

Model reduction:

The analysis system of the building structure is reduced to the more generalized system by using the Rayleigh Ritz method. This method is dependent upon the time load factor and the Ritz vector. The equations of the eigenvalue problems are reduced and they are sold by using the eigenmodes and the respectiveeigenfrequencies are calculated and analyzed preacher mainly affected by the time dependent load and this numerical analysis is presented in the systematic manner to get the precise dynamic model of the explosion building structure.

4.7 Case 2:

Velocity model:

In the velocity model we are considering the impulse load which is acting according to the initial velocity and in this case the momentum and the impulse force are related and the numerical time for the explosion is taken into consideration. Time dependent variable which is the load factor is placed in accordance with the nodes of the building and the maximum displacement in all six stories are dynamically analyzed. The reduced model is taken into consideration as a more generalized system in which the velocities of the Ritz vector are considered and they are transformed into the original system in which the actual response is noted down when the explosion occurs.

5. Findings:

The structural analysis of the building is conducted and it was performed by using the etabs software in which the each loading conditions are tested. The deflections at the columns of the building in both horizontal and vertical are taken into considerations for each loading conditions and identically the catastrophic failure is also analyzed with the variations in the time as it is shown in the case 1,2,3. The main response of the loading conditions after the analysis are done and it suggests that the oscillations of the building where almost near to the zero. The top peak pressure distributions and the deformations of the buildings are noted down in which some permanent displacement in the horizontal and vertical directions of the columns due to the blast loads have happened in the time intervals.

The results of the analysis says that the gravity load is initiated before applying the loads on the 2 dimensional frame structure of the building. When the initial load is applied on the structured we get the serviceability rate of 25% from the ground column and this load model is basically loaded at normal operating conditions. A second degree analysis of elastoplastic is conducted by using the etabs software in which the different blast load cases are studied and analyzed as shown in the table.The influence of the blast and its response on the 2 dimensional building structure is also studied under different cases in which it shows that the propagation of damage in the entire storey building drift is due to the high impulse of the energy generated when the explosion occurred and this is the exact reason for the level of damage to the building structure. When high energy impulse of the blast causes the severe damage to them the building components we can say that there will be a significant deformation in the whole structure.The analysis shows that the propagation of the deformation in the reinforced frame is reasonably due to the critical zone blast in which the blast pressure is associated withthe structural response and the rate of propagation of the explosion. The initial response of the blast in the two dimensional reinforced frame structure is analyzed with different fringe levels and this fringe levels is having a variation from zero to two and the highest position of level 2 defines that there will be a maximum yielding of the concrete structure.

From the etabs result we can say that the lower floors of the multi Storey building experienced major damage to the concrete structures then the upper stories of the building. As the height of the multi Storey building increased the frames which are

subjected to the explosions where undamaged and the rate of damage propagation took place at the ground column and the structure was completely safe to operate with only minor repairing tasks.

6. Results & discussion:

6.1Base:

The damage propagation in the reinforced multi Storey building structure after analysis revealed that The response of the building structure is basically due to the inter story drift that is occurring when the explosion takes place and the high impulsive blast forces which are mainly caused due to the structural component damage will produce higher deformation which leads to the propagation of the damage. Accordingly the blast analysis case for every story was analyzed and accordingly the pressure and impulsive forces are calculated as shown in the table. The reinforced concrete structure experienced the same type of damage caused in the base due to the ground column and all the components situated within these structures where completely in the state of elasticity and the stability was difficult to restore due to the blast pressure distributions.

TABLE: Base Reactions

Output Case	Case Type	Step Type	FX	FY	FZ
			kN	kN	kN
Non-linear d	NonStatic	Max	0	0	17161.7
Blast load	NonDirHis	Max	67.0181	63.1521	17161.7
Non linear Li	NonStatic	Max	0	0	4730.4
DL+LL	Combination		0	0	20315.3

Figure 3. Base reactions

TABLE: Story Max Over Avg Drifts

Story	Output Case	Case Type	Step Type	Direction	Max Drift
					mm
Story5	Non-linear d	NonStatic	Max	X	0.06
Story5	Blast load	NonDirHis	Max	X	0.06
Story5	Non linear Li	NonStatic	Max	X	0.019
Story5	DL+LL	Combination		X	0.073

Figure 4. Drift of the multi storey building after analysis

Storey 1:

In the story one which is witty reinforced concrete structure has almost the similar damage as compared to the base and this damage was only subjected to the ground column and the entire components of the basic building structure where in the state of elasticity and were restored after the minimization of the pressure of the blast.

They effective strain that is developed in the lower part of the building structure states that the damage to the multi Storey building reinforced concrete structure where in the fringe level of two and the columns were directly exposed to the explosion which resulted in the minor damage at the lower areas of the column and major damage to the higher ends of the column. The storey beams at the lesser levels up to the second story behaved to the explosions and experienced moderate damages at the midspans and showed the major cracks at the ends. After the displacement of the plastic hinge regions the zone of critical failure was developed due to the explosion which indicates they major cracks in the building structures.

Storey 2:

From the damage analysis of the multi Storey building the story two experienced measured displacements at the top roof of the reinforced frame and all the frames were safe and there was no sign of major damages. Accordingly the blast analysis for the story

2 was analyzed using the Strain diagram and the damage at the middle heights and the lower parts of the story where subjected to the higher drifts and these drifts with negligible which caused minor notable cracks without large lateral deformations.

Storey 3:

The reinforced concrete frame structure was analyzed using etabs model in which the concrete structure was subjected to the major critical deformations and after analysis we can say that the steel reinforcement in the building structure was undamaged. The pressure which is produced from the blast was also influenced to the higher column flows at the third floor but the beams at the third floor where subjected to the mere damages as compared to the lower floors this is due to the direction in which the explosion occurred.

Storey 4:

The damage analysis that was carried out for the two dimensional reinforced concrete structure frame in the fourth story suggested that the frame was subjected to minor damages as compared to the blast analysis of the second and the third floors and there was considerably no damages with minor cracks at the bottom of the columns and at all the ends of the beams there was little damage due to the explosion and the structure attained the complete elasticity. The propagation of the damage in this story was studied where the column was subjected to the shear force and fracture damages under the type one loading cases and the results suggested that the frame was stable and there were less lateral displacements in the reinforced structure. The strain diagram showed that the analysis of the multi Storey building has undergone some critical damage at the ground column region which is influenced by the near explosion.

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story5	15	Top	0.062	0.002
Story4	12	Top	0.047	0.002
Story3	9	Top	0.031	0.001
Story2	6	Top	0.016	0.001
Story1	3	Top	0.005	1.897E-04
Base	0	Top	0	0

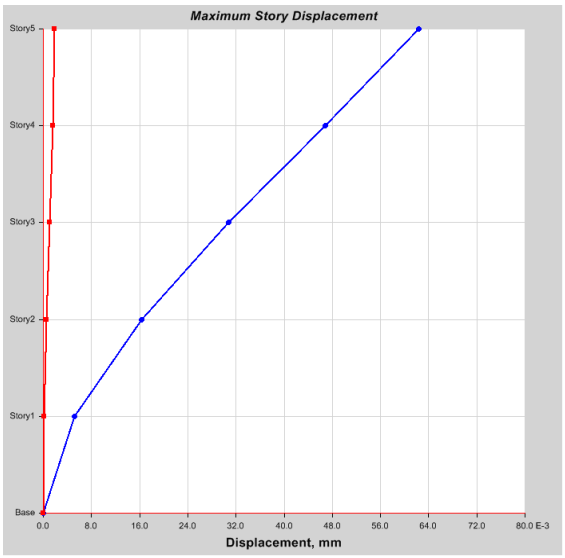

Figure 5. Maximum storey displacement grap

Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN-m	kN-m
Story5	15	Top	0	0
Story4	12	Top	0.125	7.3763
Story3	9	Top	0.3648	21.4042
Story2	6	Top	0.6807	39.8109
Story1	3	Top	1.0376	60.5316
Base	0	Top	1.4076	81.9834

Over turning results

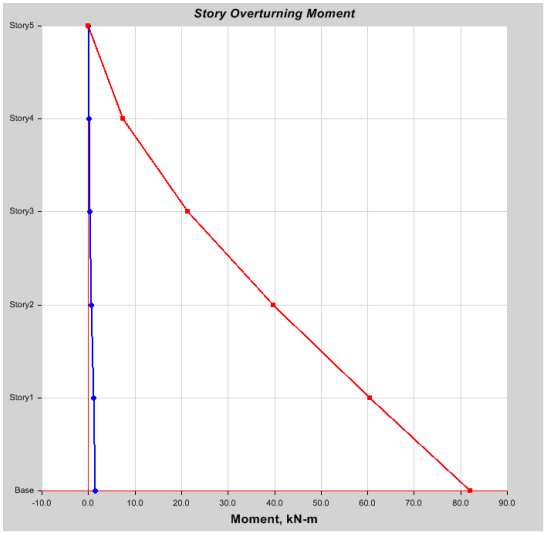

Figure 6. Over tuning v/s moment graph of multi storey building

7.CONCLUSION:

The structure is stable by providing a shear wall on all the faces of building. We can observe that the effect of blast is reduced with the increase of distance from source to the various structural components. The main aim of the project is to attain stability of the structure with minimum destruction on the model.

The scope for future enhancement is instead of applying shear wall to reduce the effect of blast loads the absorption of blast energy can be done by providing shock absorbers at various points of the structure to nullify the consequences that occur by explosives.

This research which is investigated for the determination of the blast response and the analysis of the damage of the multi Storey building which is subjected to the explosion using the trinitrotoluene suggested that The load bearing capacities of the building elements are the most vulnerable components in the damage evaluation and we can implement this model of analysis in the industrial real world applications which can contribute to develop new structural designs in the construction area.

This research involved some of the major areas of the construction engineering such as:

- Identification of the blast load parameters.
- Techniques to be used in the finite element analysis.
- Behavior of the structural components when subjected to the high stress effects.
- The dynamic time analysis of the structural components.

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