Prediction of Blast Loading and its Impact and Remedial Measures on Building

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Abstract: ***Concrete is the main constituent material in many structures. The behavior of concrete is assumed to be linear but it was proven by the experimental results that concrete is a non linear material. The stress-strain behavior of concrete was demonstrated to be highly non-linear, even at very low stress levels. Due to these reasons understanding exact behavior of concrete structure is very difficult .But due to introduction of advanced computing techniques equipped with finite element methods (FEM) it is possible to make non linear model of concrete. However, the complex behavior of concrete creates limitation in implementing FEM. The complexity is mainly due to non linear stress-strain relationship under multi axial stress conditions, strain softening and anisotropic stiffness reduction, progressive cracking and bond between concrete and reinforcement. Overcoming all these limitation is key in predicting non linear behavior of concrete. Non linear analysis can be done in many software such as ANSYS, ABAQUS, NASTRAN and ADINA. All these are not ready made applications which can work automatically on just giving commands and input data. To work in any of this software required knowledge of finite element method and firm understanding of concrete behavior. Among these software ABAQUS is capable of simulating complex geometrically non linear and material model. In this study a 3D reinforced concrete frame will be modeled in ABAQUS by using concrete damage plasticity model. Concrete damaged plasticity model works on Druker-Prager model which has to be totally understood and implemented for creating material model of concrete. The frame which is to be modeled will be subjected to lateral and gravity loading so as to understand local and global mechanisms of structural response.***

Keywords: blast load, abaqus, concrete behavior, FEM**.**

1. Introduction

One of the most important aspects of building a numerical model to estimate the effects of blasting on paste fill is to ensure that a representative blast load is applied to the model. A number of methods of applying a blast load are available. The most suitable method of applying a blast load to a numerical model is dependent on the purpose of the model. For this project, it is necessary that the blast loading function is representative of loads applied to the blast hole walls during a blast, and is numerically efficient. The different methods of applying blast loads available in ABAQUS/Explicit and the method chosen for this project are discussed in this chapter.

ABAQUS is a suite of powerful engineering simulation programs, based on the finite element method that can solve problems ranging from relatively simple linear analyses to the most challenging nonlinear simulations. ABAQUS contains an extensive library of elements that can model virtually any geometry. It has an equally extensive list of material models that can simulate the behavior of most typical engineering materials including metals, rubber, polymers, composites, reinforced concrete, crushable and resilient foams, and geotechnical materials such as soils and rock. Designed as a general-purpose simulation tool, ABAQUS can be used to study more than just structural (stress/displacement) problems. It can simulate problems in such diverse areas as heat transfer, mass diffusion, thermal management of electrical components (coupled thermal-electrical analyses), acoustics, soil mechanics (coupled pore fluid-stress analyses), and piezoelectric analysis. ABAQUS offers a wide range of capabilities for simulation of linear and nonlinear applications. Problems with multiple components are modeled by associating the geometry defining each component with the appropriate material models and specifying component interactions. In a nonlinear analysis ABAQUS automatically chooses appropriate load increments and convergence tolerances and continually adjusts them during the analysis to ensure that an accurate solution is obtained efficiently.

2. Objectives

Based on the literature review presented in Chapter 2, the salient objectives of the present study have been identified as follows:

1) To analyze the structures against the abnormal loading conditions like blast loads, strong wind pressure etc. requiring detailed understanding of blast phenomenon.
2) To study the dynamic response of various structural elements like column, beam, slab and connections in steel and RCC structures.
3) To provide protection for the building from bomb blast

3. Methodology

First of all the problem has been define, for analysis purpose a concrete beam is taken considering various support conditions such as simple supported, fixed and hinged supports. Defining material properties will be the in second step of problem definition material properties was defined. Material properties include tensile, compressive and shear behavior of concrete. These material properties had been defined in ABAQUS. Among these models concrete give best results in Druker Prager model so it that model has been used for modeling concrete in ABAQUS.

3.1 Material model

Concrete damaged plasticity model requires the following material functions stress-strain relations for the uniaxial behaviours under compressive as well as tensile loadings including cyclic unloading and reloading functions for the evolutions of the damage variables dc and dt under compressive and tensile loadings, respectively. Following are the values of stress and strain from experimental study obtained as input values.

Table 1: stress-strain values

stress	strain
0	0
12	0
13	2.00E-05
14	3.00E-05
15	6.00E-05
16	7.50E-05
17	0.00011
18	0.000145
19	0.00019
20	0.000245
21	0.00032
22	0.000415
23	0.00055
24	0.0008
24.35	0.000983
24.35	0.001083
24	0.0013
23	0.0017
22	0.001975
21	0.00221
20	0.00243

Following are the CDP (Concrete Damage Plasticity) parameters used for creating concrete are shown in Figure1

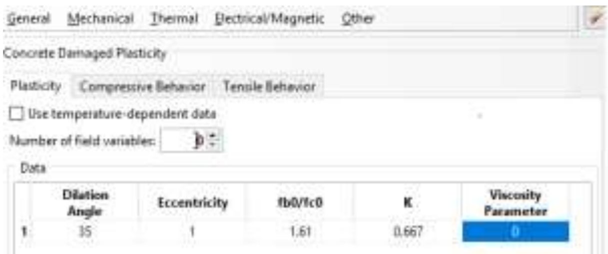

Figure 1: Concrete Damage Plasticity

Steel has been treated as linear material with on elastic properties with density 7.8t/m^3 and poisons ration as 0.3 as shown in Figure 2

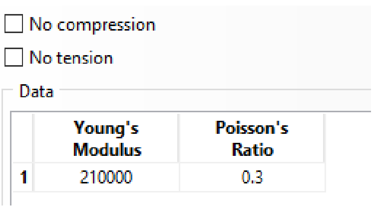

Figure 2: Steel property

3.2 Modeling of geometry

Following model of the frame has been created in ABAQUS/CAE by using modeling tree in ABAQUS 6.13.and Load in the form of blast which had been converted into udl was applied on frame as shown in Figure 3

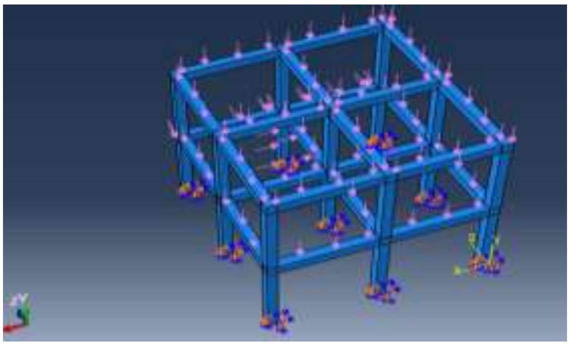

Figure 3: Loading on the model

The base of the frame has been fixed in X and Y direction but movement has been allowed in negative Z direction up to 10 mm distance.

3.3 Interaction definitions

Tie property has been used to define the interaction between beam-column and column-column joints. ABAQUS/CAE defaults values are used to define master and slave surfaces. It can be seen in Figure 4

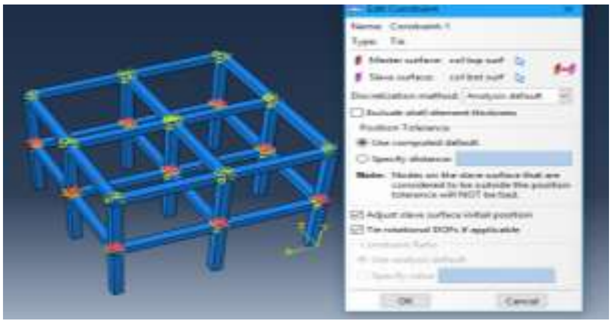

Figure 4: Constraint of the frame

3.4 Meshing

The meshing has been done by using references of previous work done in the blast loading in order to avoid the repetition of work mesh size has been selected as 25 mm. C3D8R element with hourglass effect and Reduced integration has been used for solid element and T3D2 elements were used for reinforcement elements as in Figure 5

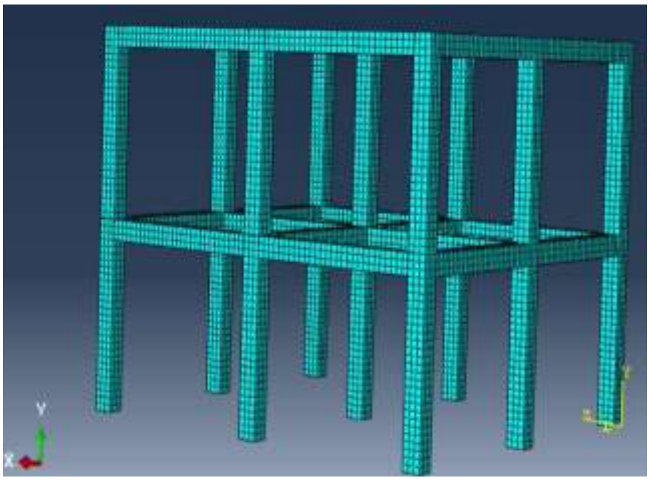

Figure 5: Mesh of the frame

3.5 R C Column Subjected To Blast Loading

A ground floor column 6.4m high of a multi-storey building was analyzed in this study Figure 6. The parameters considered were the concrete strength 40MPa for Normal strength column (NSC) and 80 MPa for High strength column(HSC) and stirrups spacing is 400mm for ordinary detailing and 100mm for special seismic detailing. It has been found that with increasing concrete compressive strength, the column size can be effectively reduced. In this case the column size was reduced from 500 x 900 mm for the NSC column down to 350 x 750 for the HSC column details given in Table 2, while the axial load capacities of the two columns are still the same. The blast load was calculated based on data from the bombing report with a stand-off distance of 5 m. The simplified triangle shape of the blast load profile was used Figure 7. The duration of the positive phase of the blast is 1.3 milliseconds.

Table 2: Concrete grades and member size

Column	Sizes	Grade of concrete(f_{ck})	Stirrups spacing	Detailing
NSC	500x900	40 N/mm^2	400mm	ordinary
NSC	500x900	40 N/mm^2	100mm	seismic
HSC	350x750	80 N/mm^2	400mm	ordinary
HSC	350x750	80 N/mm^2	100mm	seismic

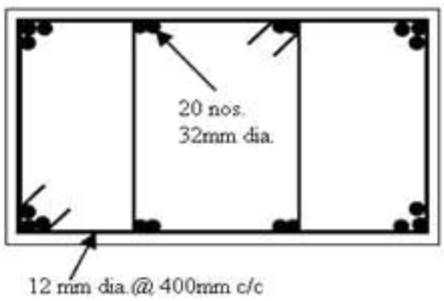

Figure 6: Cross section of the NSC column

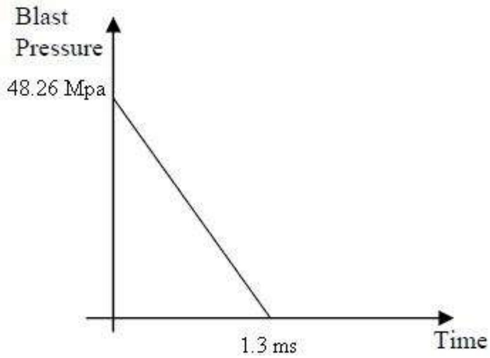

Figure 7: Blast load profile

The duration of the positive phase of the blast is 1.3 milliseconds. The 3D model of the column was analyzed using the ABAQUS which takes into account both material nonlinearity and geometric nonlinearity. The effects of the blast loading were modeled in the dynamic analysis to obtain the deflection time history of the column.

3.6 Mesh refinement analysis for fixing size of mesh

A concrete wall simulation has been created for fixing size of mesh used for further study. An experimental blast data has been used and analysis has been done by using various mesh size. The mesh size which gives results close to experimental data has been selected, which 25 mm mesh size was shown in Figure 8 and Figure 9 shows the deflection in the frame. Deflection of the column was also plotted and shown in Figure 10

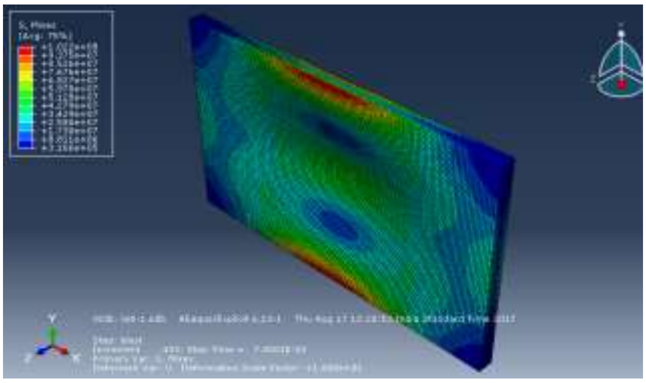

Figure 8: Deflection of Concrete wall

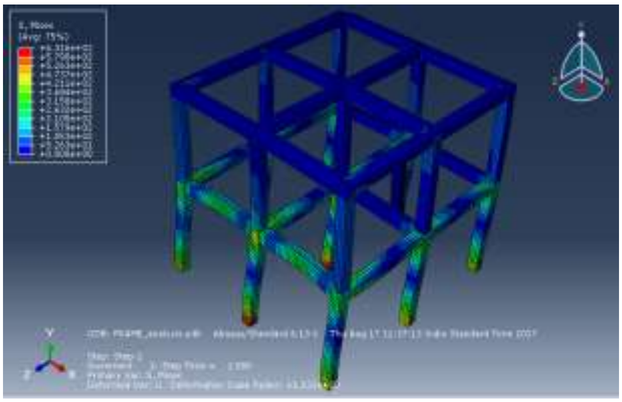

Figure 9: Deflection of Frame

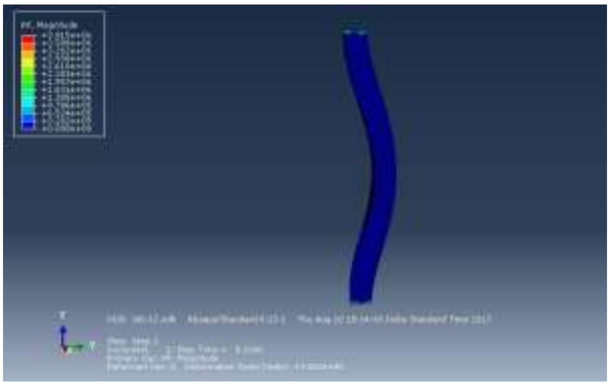

Figure 10: Deflection of column

3.7 Analysis of Frame under blast loading

The RCC frame modeled has been subjected blast loading of intensity 10N/mm^2 and simulation is done considering Dynamic-Explicit steps and results were obtained. The stress strain curve obtained at maximum stress point shows breaking of concrete at maximum stress of 24 N/mm^2 as the damping factor for concrete has been kept 5% there has been are bond of beam in the negative strain as seen in the Figure 11

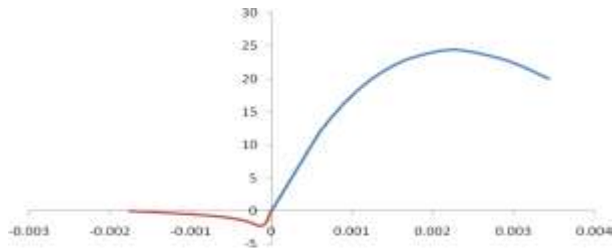

Figure 11 Non-liner stress strain behavior

While applying the blast load, all imposed loads has been suppressed in order to get the clear idea of effect of blast loading. After getting deflection a load Vs defection curve is plotted along with various mesh size and results are tabulated in Table 3. Results are plotted in Figure 12

Table 3: load Vs defection curve.

Load	Deflection for 20 m mesh size (m)	Deflection for 25 m mesh size (m)	Deflection for 30 m mesh size (m)	Deflection for 35 m mesh size (m)
5	0	0	0	0
10	0.009	0.008	0.005	0.0082
15	0.014	0.01	0.018	0.012
20	0.021	0.014	0.016	0.0155
25	0.026	0.018	0.02	0.019
30	0.031	0.022	0.025	0.0231
35	0.034	0.027	0.032	0.0283
40	0.038	0.036	0.032	0.0341

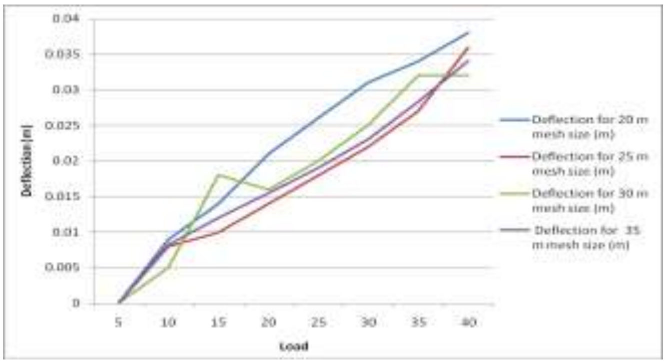

Figure 12: Results of Deflection

4. Remedial Measures

Treatment provided to various part of a structure to improve Blast Resisting Mechanism.

4.1. Floor Slabs

1) More attention must be paid to the design and detailing of exterior bays and lower floor, which are the most susceptible to blast load.
2) If vertical clearance is problem, shear heads embedded in the slab will improve the shear resistance and improve the ability of the slab to transfer moment to the columns.
3) In exterior bays/ lower floors, drop panels and column capitols are required to shorten the effective slab length and improve the punching shear resistance.
4) The slab – column interface should contain closed –hoop stirrup reinforcement properly anchored around flexural bars within a prescribed distance from the column face.
5) Bottom reinforcement must be provided continues through the column. This reinforcement serves to prevent brittle failure at the connection and provides an alternate mechanics for developing shear transfer once the concrete has punched through.

4.2 Beams

1) Balanced design often leads to a strong column - weak beam approach, with the intent that beam failure is preferable to column failure.
2) Provide sufficient shear transfer to floor slabs so that directly applied blast loads can be resisted by the diaphragms rather than weak-axis beam bending.
3) Transfer girders should be avoided in regions identified as having a high blast threat.

4.3 Column

1) The potential for direct lateral loading on the face of the columns, resulting from the blast pressure and impact of explosive debris, requires that the lower floor column be designed with adequate ductility and strength
2) The perimeter column supporting the lower floor must also be designed to resist this extreme blast effect.
3) Encasing these lower – floor column in a steel jacket will provide confinement increase shear capacity, and improve the column ductility and strength. An alternative, which

provide similar benefits, is to embed a steel column within the perimeter concrete column or well section.

4.4 Shear wall

1) Use a well distributed lateral load mechanism in the horizontal floor plan. This can be accomplished by using several shear walls around the plan of the building this will improved the overall seismic as well as the blast behavior of the building.
2) If adding more shear wall is not architecturally feasible, a combined lateral load resisting mechanism can also be used.
3) A central shear wall and a perimeter moment resisting frame will require strengthening the spandrel beams and the connections to the outside columns. This will also result in better protection of the outside column.

5. Stand- Off Distance

1) As we all know, the greeter the stand -off distance, the more the blast forces will dissipate resulting in reduced pressure on the building. Several recommendations can be made to maintain and improve the stand- off distance for the building under consideration.
2) Use anti-ram bollards or large planters, placed around the entire perimeter.
3) The public parking lot at the corner of the building must be secured to the guarantee the prescribed keep out distance from the face of the structure. Preferably the parking lot should be eliminated.
4) Street parking should not be permitted on the near side of the building.

6. Conclusions

Based on the studies available in the literature, the ultimate objective is to make available the procedure for calculating the blast loads on the structures with or without the openings and frame structures. Also to study the dynamic properties of reinforcing steel and concrete under high strain rates typically produce by the blast loads. From this part of the study, an understanding of how reinforced concrete columns respond to blast loads was obtained.

The following observations and conclusions are drawn from this study
1) The surfaces of the structure subjected to the direct blast pressures cannot be protected; it can, however, be designed to resist the blast pressures by increasing the stand-off distance from the point of burst.
2) For high-risks facilities such as public and commercial tall buildings, design considerations against extreme events (bomb blast, high velocity impact) are very important.
3) It is recommended that guidelines on abnormal load cases and provisions on progressive collapse prevention should be included in the current Building Regulations and Design Standards. Requirements on ductility levels also help to improve the building performance under severe load conditions.

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