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BEHAVIOR OF REINFORCED CEMENT CONCRETE MULTISTOREY BUILDING UNDER BLAST LOADING

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Abstract - *A critical study is presented in this report to estimate the blast loading and its dynamic effects on various component of MDOF structure. This study could be done analytically by developing the MATLAB codes for MDOF systems. However the analytical findings of MATLAB program results for some standard cases are going to verify over the finite element software. Two models of MDOF fixed base system with and without blast loading is being considered for the study. The subsurface blast explosion is only being considered for the study over MATLAB, However the surface and subsurface blast explosion is being considered for the study of 3D building over FE software package. The positive impulsive triangular load is only being considered for the time history analysis. For the present study the material behavior is restricted to linear elastic only.*

The mathematical formulation of MDOF systems are solved by using New mark Beta implicit step by step integration method. The entire study is focused on time domain form only. The structural output results are measured in terms of structural displacement, absolute acceleration, storey shear force and base shear. The analytical investigation is being carried out for the blast load parametric prediction. In the present study, the effective blast resistant technique for the protection of structural components could also been suggested.

Keyword's: *- MDOF, Blast Loading, Blast resistance techniques, SAAP 2000 NL, MATLAB*

1.INTRODUCTION

An explosion as a very fast chemical reaction during which a rapid release of hot gases and energy takes place. During explosion in air the hot gases that are produced expand in order to occupy the available space, leading to wave type propagation through space that is transmitted spherically through an unbounded surrounding medium. This phenomenon is termed as air burst. A schematic representation of blast load that occurs very close to ground surface and termed as surface burst. In the present study, the surface and subsurface blast phenomenon is studied. The phenomenon lasts only for some milliseconds and it results in the production of very high temperatures and pressures capable to cause catastrophic damage to structures and human life. Several factors govern the magnitude of blast load on structure during an explosive detonation namely charge weight, standoff distance, geometric configuration of structure and orientation of structure. The power of the blast primarily depends on the charge weight and standoff distance with the former expressed as the equivalent weight of Trinitrotoluene (TNT) that the building will encounter. Range or stand-off is calculated with reference to the center of gravity of the charge situated in the vehicle or the structural member.

The common effects of blast load on structure includes damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. The major sources of blast load includes heinous terrorists' activities and accidental explosions that results in large dynamic loads.

Explosives and bombs are categorized as small medium and high or large:

Small explosive devices up to 5 kg TNT, Medium explosive devices up to 20 kg TNT

Large explosive devices and bombs up to 100 kg TNT, Very large explosive devices and bombs up to 2500 kg TNT.

2. MATERIALS

2.1 Structure Details

In the present study a G+2 reinforced cement concrete building considered under the blast load. the storey height is 3.2 m. All beam sizes are 0.23*0.4 m & column sizes are 0.4*0.4 m. slab thickness are 0.12 m. the intensity of live load is . KN/m^2. Used M25 grade of concrete.

For the present study the material behavior is restricted to linear elastic only.

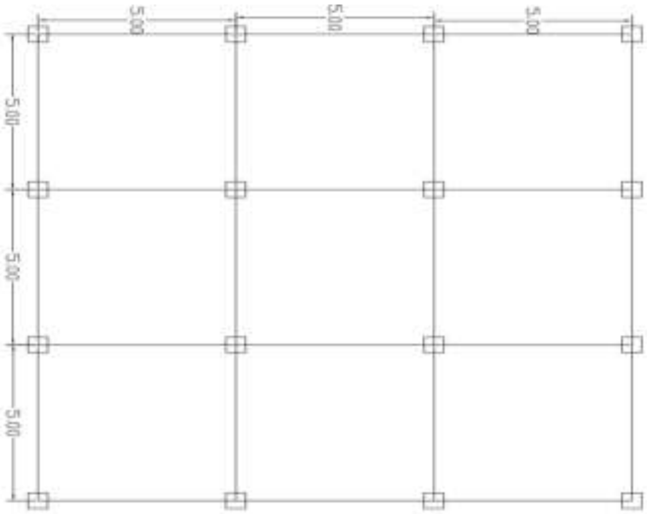


Fig 1 : Line Plan

2.2 Methodology

2.2.1 Structure Modelling

Fig 2 Lumped Mass Model

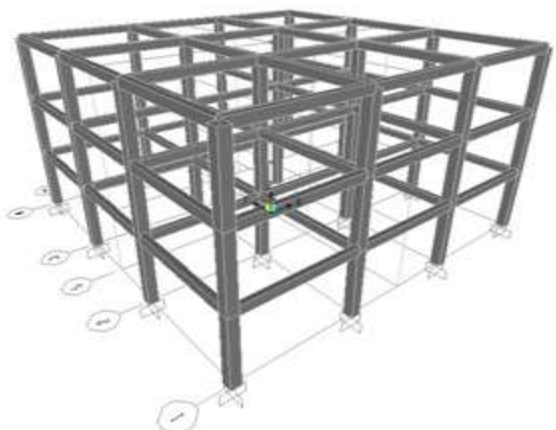


Fig 3 3Dimensional Model

A Three dimensional has independent displacement at each node and can simulate any tpye of behavior. Because of the difficulties in modeling, verification. Verification and numerical calculation, the three dimensional model has not yet been used even in the most sophisticated design practices. Figure 2.2.1(b) shows three dimensional frame model which is especially useful to simulate the responses of three dimensional effect such as,

1) Building with geometric configuration
2) Torsional response in the structure with eccentric distribution of stiffness or mass, and
3) Earthquake motion in two directions or in skewed direction etc.

A lumped mass model is simple and most frequently used in early times for practical design of multi storey building. It reduced the substantial amount of calculation and storage in comparison to two dimensional frame models. The soil structure interaction model takes into account the possibility of having different horizontal and vertical motion of support, modifications of the natural period of structure due to interaction with the soil, changing of the base motion in comparison to the motion in free field, increasing the effective damping due to difference between the tenancy of regular structure motions.

2.2.2 Elastic Time History Analysis

A linear time history analysis overcomes all the disadvantages of modal response spectrum analysis. One interesting advantage of such procedure is that the relative sign of response quantities are preserved in the response histories.

2.2.3 Time History Method

A step by step procedure for analysis of frame by time history method is as follows:-
The equation for MDOF system in matrix form can be expressed as,
$[m]\{\ddot{X}\} + [c]\{\dot{X}\} + [k]\{X\} = -\ddot{X}_g(t)[m]\{I\}$
Where,
[M] = Mass Matrix
[K] = Stiffness Matrix
[C] = Damping Matrix
{I} = Unit Vector
$\ddot{X}_g(T)$ = Ground Acceleration.
The solution of equation of motion for any specified forces is difficult to obtain mainly to coupling of the variables {X} in the physical coordinates In a modal analysis a set of normal

coordinates i.e. principal coordinates is defined, such that, when expressed in those coordinates, the equations of motion become uncoupled The physical coordinates {X} may be related with normal or principal coordinates (q) from the transformation expression as,

$\{X\} = [\Phi] \{ q \}$

$[\Phi]$ is the modal matrix,

Time derivatives of {X} are,

$\{\dot{X}\} = [\Phi] \{ \dot{q} \}$ $\{\ddot{X}\} = [\Phi] \{ \ddot{q} \}$

Substituting the time derivatives in the equation of motion, and pre-multiplying by $[\Phi]^T$ result in,

$[\Phi]^T[m][\Phi] \{ \ddot{q} \} + [\Phi]^T[c] [\Phi] \{ \dot{q} \} + [\Phi]^T[k] [\Phi] \{ q \} = (- \ddot{X}_g(t) [\Phi]^T[m] \{I\})$

More clearly it can be represented as follows,

$[M]\{ \ddot{q} \} + [C] \{ \dot{q} \} + [K] \{ q \} = \{P_{eff}(t)\}$

Where,

$[M] = [\Phi]^T[m][\Phi]$

$[C] = [\Phi]^T[c] [\Phi]$

$[K] = [\Phi]^T[k] [\Phi]$

$\{P_{eff}(t)\} = (- \ddot{X}_g(t) [\Phi]^T[m] \{I\})$

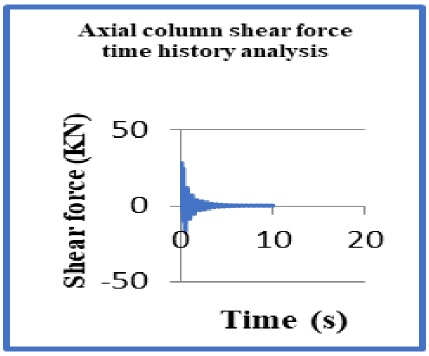
[M],[C] and [K] are the diagonal modal mass matrix modal damping matrix, and stiffness matrix, respectively, and $\{p_{eff}(t)\}$is the effective modal force vector.

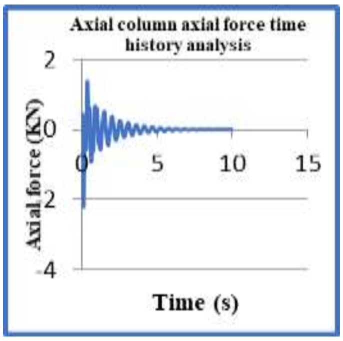
3. RESULTS

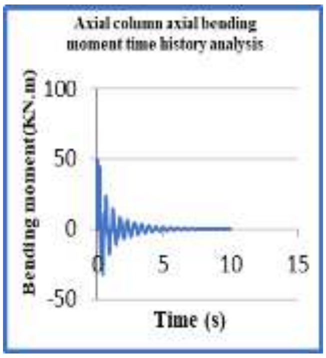
3.1 Surface Blast Loading

3.1.1 3-Dimensional Model

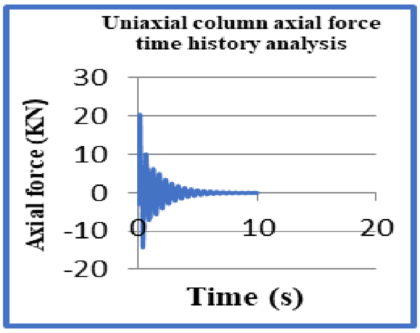
a) Axial Column Time History Analysis

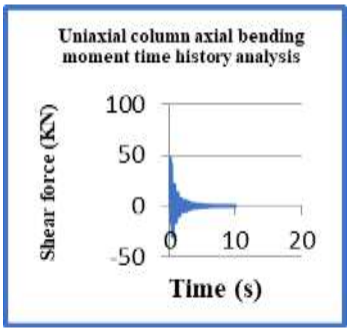


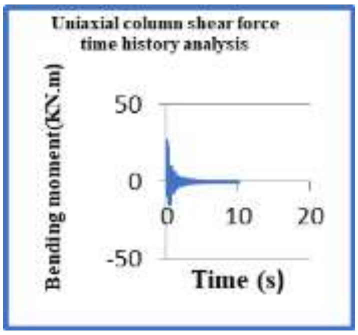




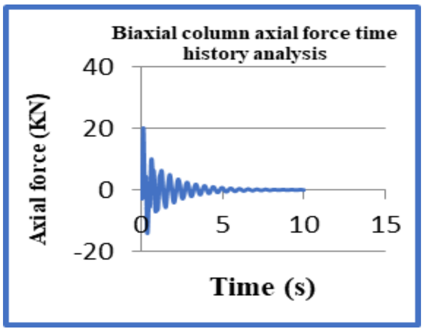
b) Uniaxial column time history analysis

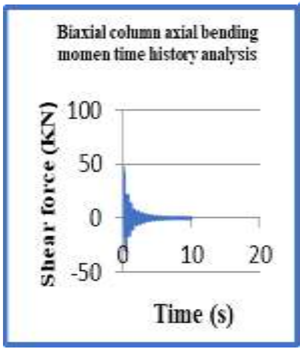


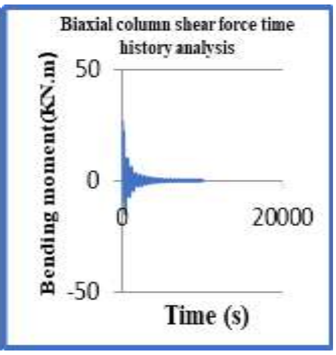




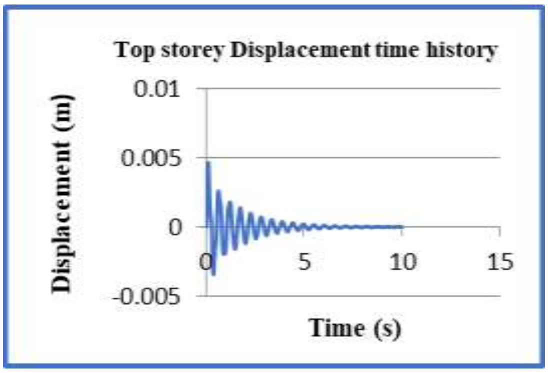
c) Biaxial column time history analysis



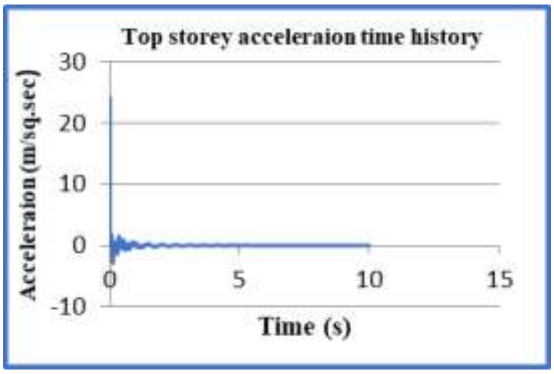




d) Top storey Displacement time history



e) Top storey Acceleration time history



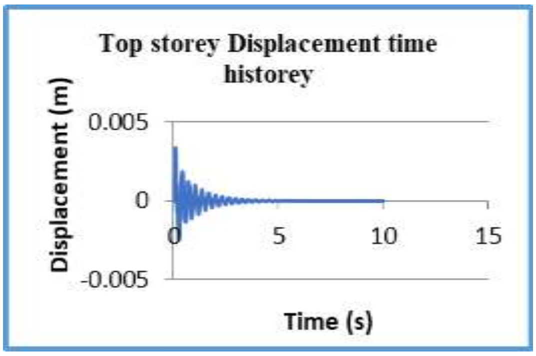
f) Base shear force

Table 1- Base Reactions

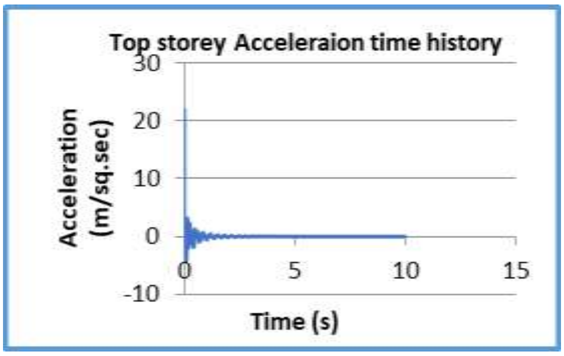
OutputCase	CaseType	StepType	GlobalFX
Text	Text	Text	KN
P	LinModHist	Max	254.705
P	LinModHist	Min	-436.819

3.1.2 Lumped mass model

a) Top storey Displacement time history



b) Top storey Acceleration time history



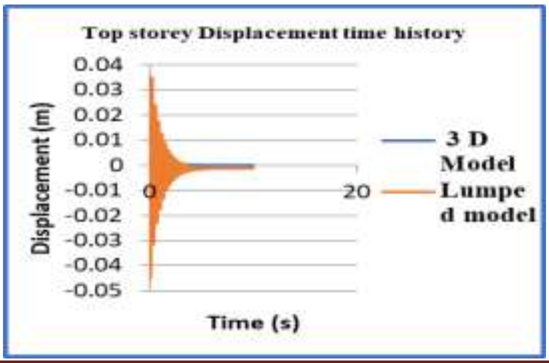
c) Base Shear Force

Table 2 – Base Reactions

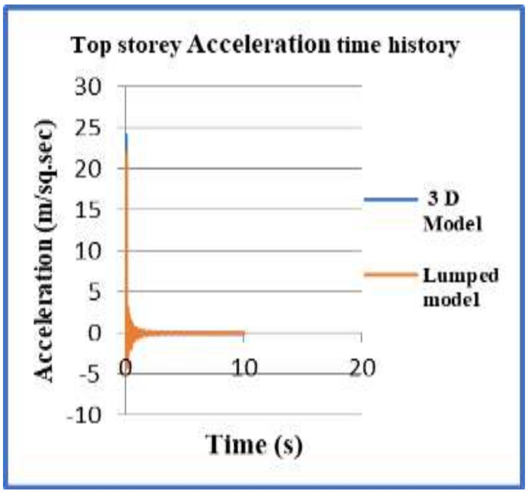
OutputCase	CaseType	StepType	GlobalFX
Text	Text	Text	KN
P	LinModHist	Max	639
P	LinModHist	Min	-478

3.1.3 Comparison between 3-D model and Lumped mass model

a) Top storey Acceleration time history



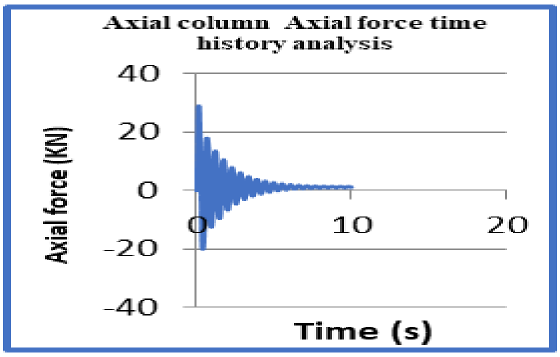
b) **Top storey Acceleration time history**

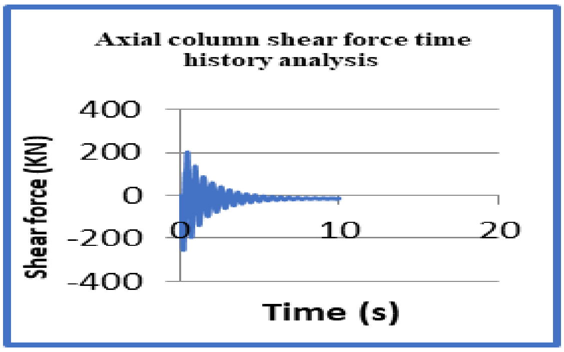


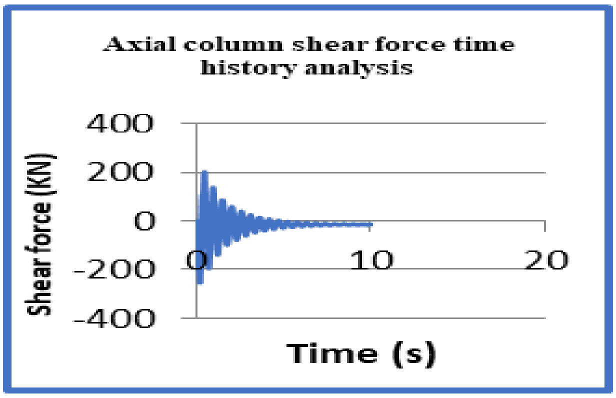
3.2: Subsurface blast loading:

3.2.1: 3- Dimensional model:

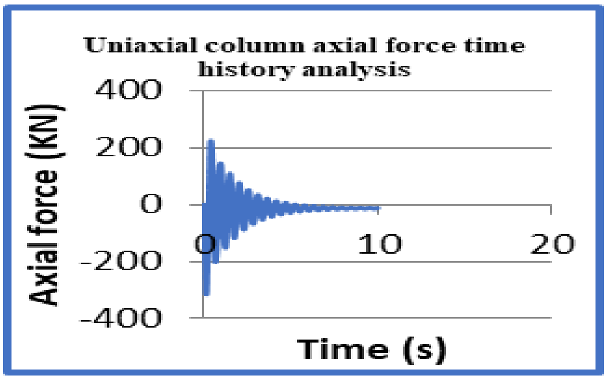
a) **Axial column time history analysis**

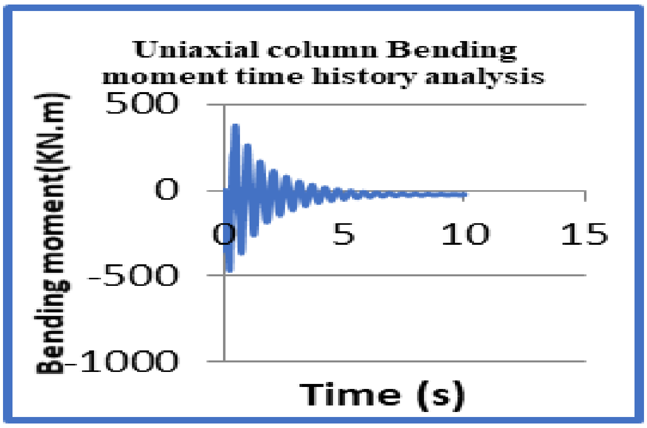


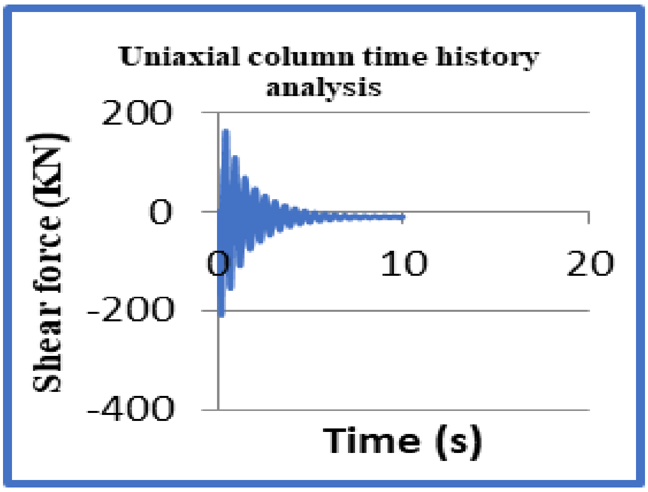




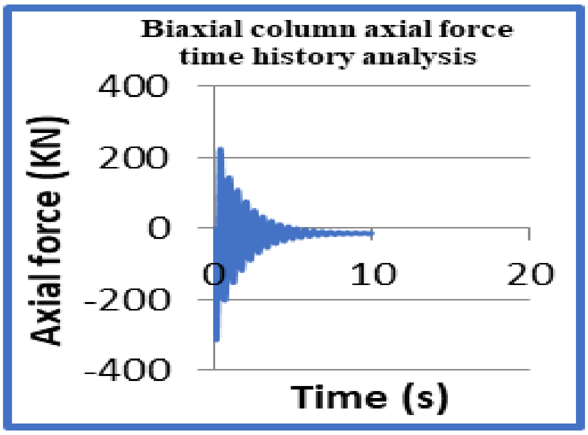
b) **Uniaxial column time history analysis**

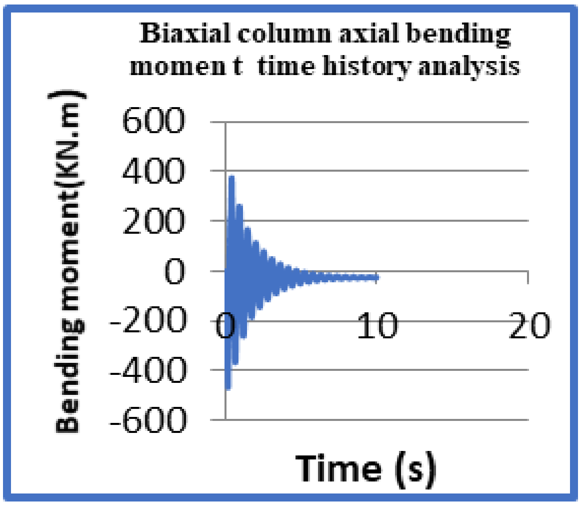


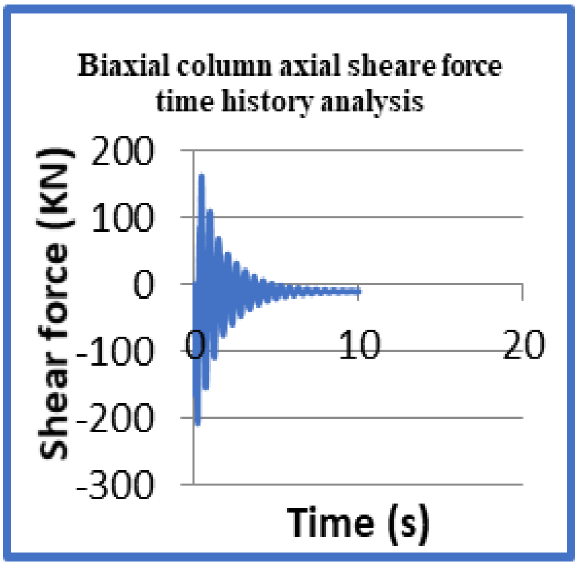




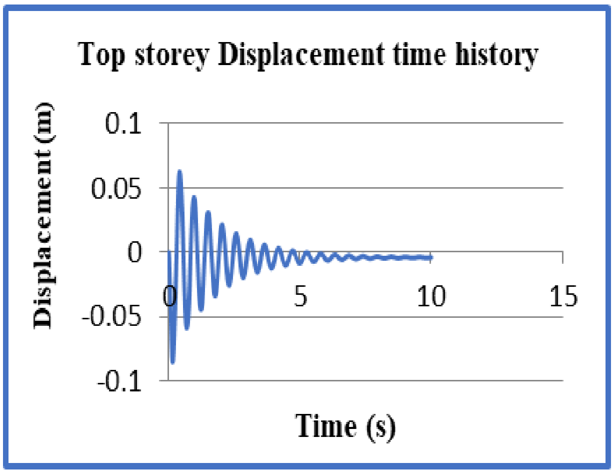
c) **Biaxial column time history analysis**



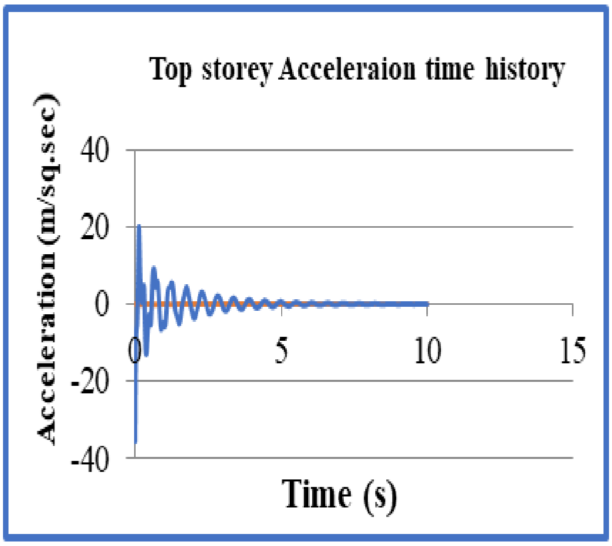




d) **Top storey Displacement time history**



e) **Top storey Acceleration time history**



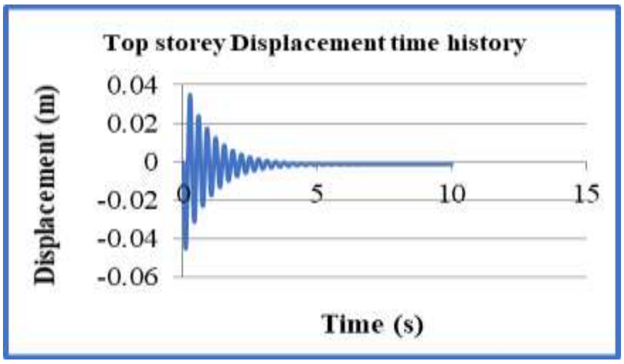
f) **Base shear force**

Table 3 Base Reactons

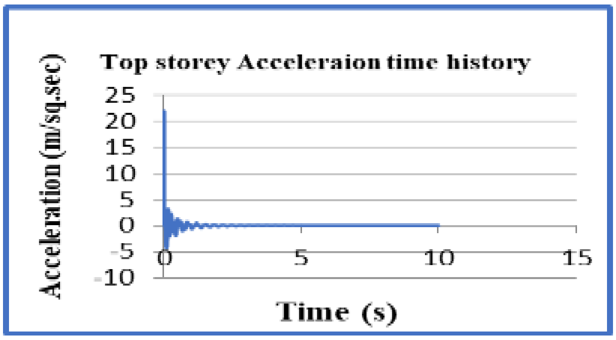
OutputCase	CaseType	StepType	GlobalFX
Text	Text	Text	KN
P	LinModHist	Max	3702
P	LinModHist	Min	-2895

3.2.2: Lumped mass model

a) Top storey Displacement time history



b) Top storey Acceleration time history



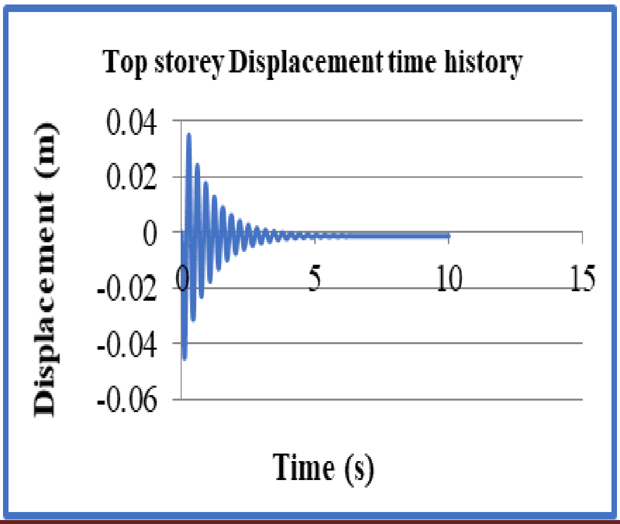
c) Base shear force

Table 4 Base Reactions

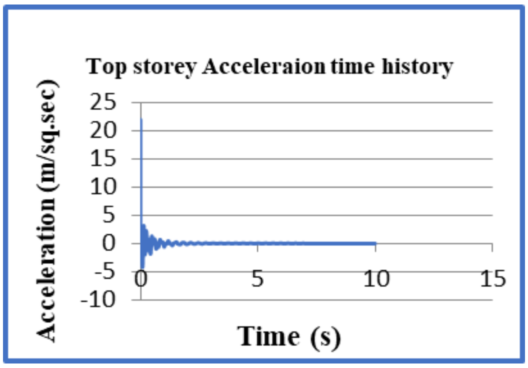
OutputCase	CaseType	StepType	GlobalFX
Text	Text	Text	KN
P	LinModHist	Max	5604
P	LinModHist	Min	-5002

3.2.3: MATLAB Programming

a) Top storey Displacement time history



b) Top storey Acceleration time history



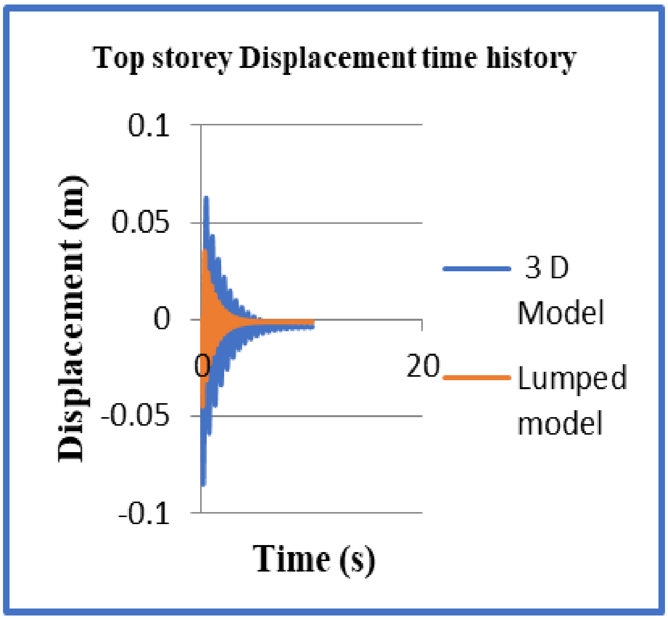
c) Base shear force

Table 5 Base Reactions

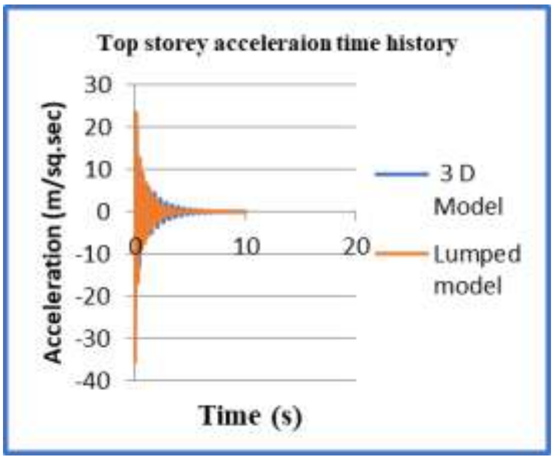
OutputCase	CaseType	StepType	GlobalFX
Text	Text	Text	KN
P	LinModHist	Max	5604
P	LinModHist	Min	-5002

3.2.3: Comparison between 3-D model and Lumped mass model

a) Top storey Displacement time history



b) Top storey Acceleration time history



4. CONCLUSIONS:

Blast load for close explosion under subsurface and surface was determined and simulated on a model building using SAP 2000NL. The surface blast loading time history is generated using W.E. Baker (1973) and apply to three dimensional building model as well as lumped mass model in SAP 2000NL, However the subsurface blast ground acceleration is calculated as per the formulation adopted by C. H. Dowdling (1985) and then it is apply to 3D building model in SAP 2000NL. The MATLAB program is also prepared for lumped mass model subjected underground acceleration due to subsurface blast. The results are noted in the form of displacement time history, acceleration time history, and base reaction time history for lumped mass model. On the other hand for 3D building, the results were obtained in the form of joint displacement time history, joint acceleration time history, joint base reaction time history, element shear force/axial force time history and element bending moment time history. Blast is an impulsive load but its effect is remaining over the structure for up to 5 second, thereafter it is diminishes very rapidly. Blast produces large amount of base shear force and moment in building which cannot be ignored while designing the structural members. The structure is vibrating much severely during the initial phase of blast. Here in the present study only linear elastic structure is considered, the plastic deformation is not being considered, otherwise there may have possibility that structure undergoes in plastic stage and failed. In surface blast, the acceleration and displacement of lumped mass model is getting 12% less than the 3D building model. In subsurface blast loading, the acceleration and displacement of lumped mass model is getting 33% less than the 3D building model. The base shear force of three dimensional building is 33% less than the lumped mass building model. The distributed Rayleigh mass is normally considered by the Finite element software during analysis, so therefore the results of 3D model and lumped mass model could not match. Here in the present study only multi storey building system is considered in which blast has induced 2g to 4g accelerations in buildings depending upon the blast charge weight and exposed distance of structure from the blast site, however in high rise building this effect could be much severe.

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