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Investigation of Dynamic Behavior of Framed Structure Under Impact Load

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Abstract: *Due to various accidental or intentional events concerning some of the most important structures in the world, explosive loads and impact loads have brought considerable attention in the recent years. Today, structural engineers need to comply with the design and construction of public buildings providing life safety in the face of explosions and heavy impact loadings. This paper represents the work of an investigative project and contains a general overview of numerical analysis and dynamic response of framed structures subjected to impact loading. The aim of the report is to introduce the reader to the Finite Element Method which is critical when analyzing dynamic response to Framed structures. In this paper the reader will be introduced to Ansys software the paper will also explain and discuss particular model cases subjected to various impact loadings. With these models the paper aims to generate a basic understanding of how the FEM works, and hopes to enable a clearer understanding of the Behavior of Framed structures showing the clear results of stress, strain and deformation transferred throughout the Structures.*

Keywords: *Framed Structure, Impact Load, Ansys, FEM, Numerical analysis, Dynamic Response Deformation,*

1. Introduction

This paper presents an Analysis method of framed structures of steel. This type of structure has the function of protecting important (safety related) equipment, structure or specific areas from the damage of projectile impact. The impacted structural member will undergo large deformation to absorb the energy brought by the projectile, without loss of its own integrity (no penetration).The effect of an impact force on structure depends on the shape, mass, and velocity of the impacting body; the contact area; the structure’s dynamic response; and the material type, etc. A significant analysis effort is required to evaluate the behavior of a structure under impact loading. In addition, several iterations have to be performed before the structure design is finalized. To simplify the design, a methodology has been developed using an equivalent static load for a framed structure under impact load. This method has been used in structural design and has demonstrated satisfactory results in meeting design criteria.

Due to various accidental or intentional events concerning some of the most important structures in the world, explosive loads have gained considerable attention in recent years. Today, structural engineers need to comply with the design and construction of public buildings providing life safety in the face of explosions and heavy impact loadings. Man-made hazards such as terrorist attacks are not the only credible extreme events that can cause staggering life and economic loss. Natural hazards including earthquakes, floods, tornadoes, fires and hurricanes have caused huge losses in the past. With regard to structures subjected to impact loading, the main issue which has recently become the focus of renewed research interest is the design and analysis of framed structures. What is likely to affect the outcome or success of structural rigidity is the type of impact the building has to restrain when subjected to various impact loadings. This will be dictated by the type of impact which the structure is subjected to, and the type of frame used when analyzing the dynamic response with the use of numerical analysis

This investigation deals with behavior of framed structure under impact loading. At first there is over all study of Dynamic behavior of frame for the Impact load. According to that studies by using the analytical methods examine the framed structure. Then by experimentally casting the model of frame structure and study it by applying impact load on it. Here impact load is by dropping mass from desired height. In this we apply impact load on framed structure from certain height and examine it by using FFT Analyzer and accelometer. Take successive reading for gradually increasing height. Now, increase the mass so impact will increases and follow the same work as above. At next, increase the bay of the framed structure and again repeat the procedure as mentioned.

Finally, compare the analytical and experimental results

1.1 Impact Load

At one time or another most engineers run into cases of impact loading. The general problem of impact is extremely complex. The physics of impact necessarily involves conservation of energy and momentum. When moving object strikes the structure the force which decelerates the mass satisfies conservation of momentum. The kinetic energy of impacting body will be partially converted to strain energy in the target and partially dissipated through friction and local plastic deformation and strain energy radiated away as stress wave. The details are very difficult to predict, but part simple estimates based on first principles can usually result is reasonable estimates for response.

Some structures must be designed for impact loads, which may result from the crashing of comparatively rigid heavy objects at low velocities, such as falling rocks in mountain areas and falling heavy loads dealt with in factories and warehouses due to accidents. A rational examination of the structural safety of the structures subjected to impact loadings is essential to develop a performance-based impact resistant design approach, in addition to currently available design specifications for impact loadings.

Impact loading, in general, is an extremely severe loading condition characterized by its application of force of great intensity within a short duration. The behavior of a structural component under impact loading may consist of two response phases; the local response due to stress wave that occurs at the loading point during a very short period after impact; and the overall response including the free vibration effect due to elastic-plastic deformation that occur over a long period in the whole structural member after impact.

1.2 Fast Fourier Transform (FFT)

The Fast Fourier Transform (FFT) is the powerful tools for analyzing and measuring signals from plug-in data acquisition devices. For example, you can effectively acquire time-domain signals, measure the frequency content, and convert the results to real-world units and displays as shown on traditional bench top spectrum and network analyzers. By using FFT, you can build a lower cost measurement system and avoid the communication overhead of working with a stand-alone instrument. Plus, you have the flexibility of configuring your measurement processing to meet your needs.

To perform FFT-based measurement, however, you must understand the fundamental issues and computations involved. This application note serves the following purposes.

1. Describes some of the basic signal analysis computations.
2. Discusses antialiasing and acquisition front ends for FFT-based signal analysis.
3. Explains how to use windows correctly.
4. Explains some computations performed on the spectrum.
5. Shows you how to use FFT-based functions for network measurement.

The basic functions for FFT-based signal analysis are the FFT, the Power Spectrum, and the Cross Power Spectrum. Using these functions as building blocks, you can create additional measurement functions such as frequency response, impulse response, coherence, amplitude spectrum, and phase spectrum.

FFT is useful for measuring the amplitude and frequency content of stationary or transient signals. FFTs produce the average frequency content of a signal over the entire time that the signal was acquired. For this reason, you should use FFTs for stationary signal analysis or in cases where you need only the average energy at each frequency line.

FFT based measurements are subject to errors from an effect known as leakage. This effect occurs when the FFT is computed from of a block of data which is not periodic. To correct this problem appropriate windowing functions must be applied. The user must choose the appropriate window function for the specific application. When windowing is not applied correctly, then errors may be introduced in the FFT amplitude, frequency or overall shape of the spectrum. This application note describes the phenomenon of leakage, the various windowing functions and their strengths and weaknesses, and examples are given for various applications.

1.3 The Finite Element Method

The finite element method (FEM) is the dominant discretization technique in structural mechanics. The basic concept in the physical FEM is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry called *finite elements* or *elements* for short. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions, at a set of nodal points. The response of the mathematical model is then considered to be approximated by that of the discrete model obtained by connecting or assembling the collection of all elements.

The finite element method (FEM), which is sometimes also referred as finite element analysis (FEA), is a computational technique which is used to obtain the solutions of various boundary value problems in engineering, approximately. Boundary value problems are sometimes also referred to as field value problems. It can be said to be a mathematical problem wherein one or more dependent variables must satisfy a differential equation everywhere within the domain of independent variables and also satisfy certain specific conditions at the boundary of those domains. The field value problems in FEM generally has field as a domain of interest which often represent a physical structure. The field variables are thus governed by differential equations and the boundary values refer to the specified value of the field variables on the boundaries of the field. The field variables might include heat flux, temperature, physical displacement, and fluid velocity depending upon the type of physical problem which is being analyzed.

A general procedure for finite element analysis comprises of certain steps which are common to all such analyses, whether fluid flow, structural, heat transfer or some other problem. These steps are sometimes embodied in the software packages used for commercial purposes. The steps can be described as follows:

i) Preprocessing:

This step in general includes:

- Defining the geometric domain of any problem.
- Defining the type of element or elements to be used.
- Defining the elemental material properties.
- Defining the geometrical properties of elements such as length, area etc.
- Defining the connectivities of elements.
- Defining the boundary conditions.
- Defining the conditions of loading.

This step sometimes also referred as model definition step is critical. It can be said that a finite element problem which is perfectly computed is of no value if it corresponds to a wrong problem.

ii) Solution:

While solving the problem, FEM assembles the governing algebraic equations in matrix form and computes the unknown values of the primary dependent variables or field variables. These primary dependent variables can then be used by back substitution to compute additional, derived variables such as heat flow, element stresses, reaction forces etc.

iii) Post processing:

It comprises of the analysis and evaluation of the solution results. It contains sophisticated routines to print, sort and plot the selected results from a finite element solution. Operations that can be done include:

- Checking equilibrium.
- Animating the dynamic model behavior.
- Plotting the deformed structural shape.
- Calculating the factors of safety.

Sorting the element stresses in order of their magnitude.

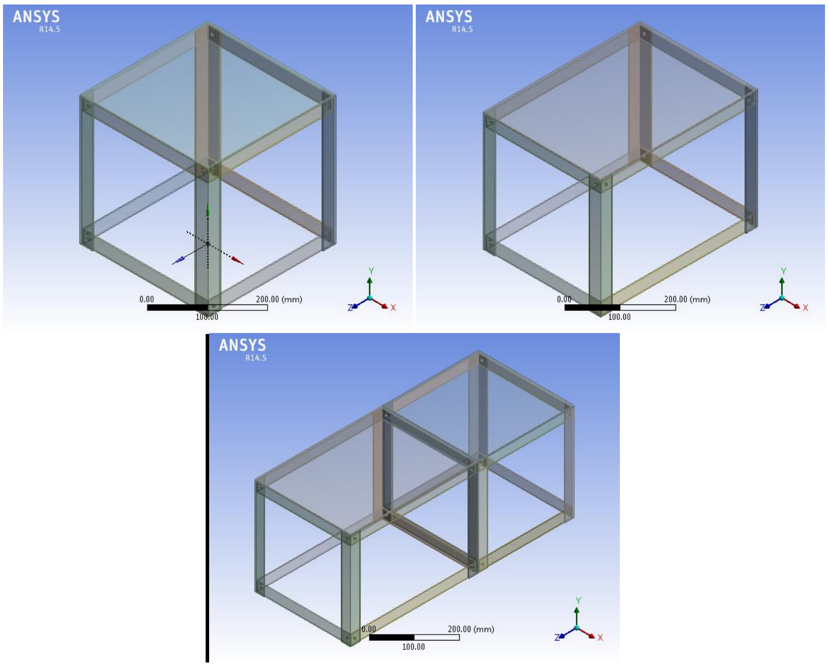
2. EXPERIMENTAL PROGRAM

2.1 Numerical Analysis

Finite element analysis/method (FEM) is a widely used method to assess the behavior of a variety of structural systems. FEM views the solution region built up of many small, interconnected sub regions or elements. The essence of FEA is to divide the body into finite elements, often just called elements. It is designed to contain the structural properties and the material which specifies how the structure will react under specific loading conditions. ANSYS 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.

2.2 Modeling of the Framed Structure

In this study, Ansys has been used to analyze the dynamic reaction of the Frame under the impact loadings. Thus the report shall successfully show the reaction to how a Frame Structure will resist impact, or blast loads and bypasses the need to perform a physical experiment which is too costly and exceeds the factors of safety. There are total 6 models of Framed Structures is made out of mild steel with the same specification with dimension of 0.3X0.3X0.3m, 0.3X0.3X0.6m, 0.4X0.3X0.3m, 0.4X0.3X0.6m, 0.7X0.3X0.3m, 0.7X0.3X0.6m. The Density used will be set as 1800 kg/m3, also specified from the journal above and is a value used in normal test data. The Young's modulus and Poisson's ratio shall be taken as 2.68x10 and 0.2. An impact loading of certain amount shall be pressurized on the framed structures within 1 second. The intensities of following amount of force applied on the top of the framed structure as impact load.



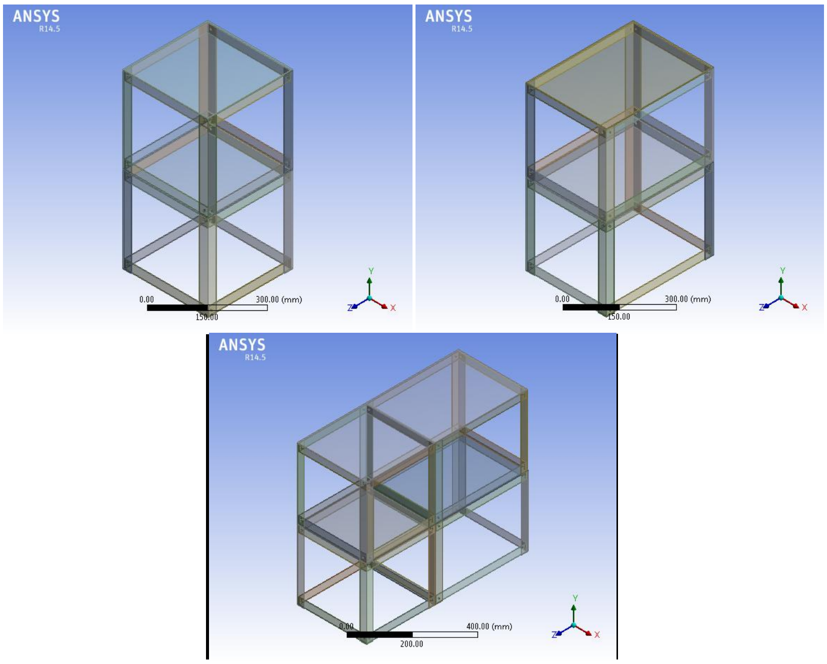


Fig 1. *Ansys Modeling of Framed Structure*

Fig 2.*Three Framed Structure and Structure Connected with FFT Analyser*

3. RESULT AND DISCUSSION

Following are the results showing comparison of the experimental and analytical results of model 0.4X0.3X0.3.Experimental analysis of impact loading on framed structure is done by using FFT analyzer and accelerometer. And, same model is making in Ansys 14.5 with same material property, material connectivity and boundary condition. Then analyze that model under same loading condition in Ansys. In following table, both results are plotted such way that first at all keep height constant and increase mass of impact load. Height varies 0.05 m to 0.5m and mass of impact varies 0.1 kg to 5 kg. Same loading conditions are apply for other model.

Table 1. *Final Impact Load on Frame*

Sr No	Height of impact In meter	Load for impact In kilogram	ANSYS amplitude in nm	FFT amplitude in nm	Sr. No	Height of impact In meter	Load for impact In kilogram	ANSYS amplitude in nm	FFT amplitude in nm
1.	0.05 m	0.1			1.	0.15 m	0.1	**101**	115
2.	0.05 m	0.2			2.	0.15 m	0.2	**203**	200
3.	0.05 m	0.3	**101**	115	3.	0.15 m	0.3	**305**	312

4.	0.05 m	0.5	**169**	172	4.	0.15 m	0.5	**509**	519
5.	0.05 m	1	**339**	331	5.	0.15 m	1	**1018**	1120
6.	0.05 m	1.5	**509**	519	6.	0.15 m	1.5	**1527**	1520
7.	0.05 m	2	**679**	652	7.	0.15 m	2	**2037**	2180
8.	0.05 m	3	**1018**	1120	8.	0.15 m	3	**3055**	2750
9.	0.05 m	5	**1697**	1710	9.	0.15 m	5	**5092**	5320

Table 2. *Final Impact Load on Frame*

Sr No	Height of impact In meter	Load for impact In kilogram	ANSYS amplitude in nm	FFT amplitude in nm	Sr. No	Height of impact In meter	Load for impact In kilogram	ANSYS amplitude in nm	FFT amplitude in nm
1.	0.05 m	0.1	**163**	172	1.	0.15 m	0.1	**203**	200
2.	0.05 m	0.2	**273**	287	2.	0.15 m	0.2	**407**	401
3.	0.05 m	0.3	**410**	401	3.	0.15 m	0.3	**611**	606
4.	0.05 m	0.5	**683**	652	4.	0.15 m	0.5	**1018**	1120
5.	0.05 m	1	**1367**	1350	5.	0.15 m	1	**2037**	2180
6.	0.05 m	1.5	**2050**	2180	6.	0.15 m	1.5	**3055**	2750
7.	0.05 m	2	**2734**	2750	7.	0.15 m	2	**4074**	4150
8.	0.05 m	3	**4101**	4150	8.	0.15 m	3	**6111**	6520
9.	0.05 m	5	**6835**	6520	9.	0.15 m	5	**10186**	-

Table 3. *Final Impact Load on Frame*

SrNo	Height of impact In meter	Load for impact In kilogram	ANSYS amplitude in nm	FFT amplitude in nm
1.	0.05 m	0.1	**339**	331
2.	0.05 m	0.2	**679**	652
3.	0.05 m	0.3	**1018**	1120
4.	0.05 m	0.5	**1183**	1710
5.	0.05 m	1	**3395**	3550
6.	0.05 m	1.5	**5092**	5320
7.	0.05 m	2	**6790**	6520
8.	0.05 m	3	**10186**	**-**
9.	0.05 m	5	**16976**	**-**

The results below demonstrate the analysis of the model under the application of 0.5 kg load fall from the height of 0.05 m it gives final impact on frame is 245 N and 0.5 kg load fall from the height of 0.15m it gives final impact on plate is 735 N in which figures for the distribution of the deformation, maximum principal stresses and the stress across the ZZ direction.

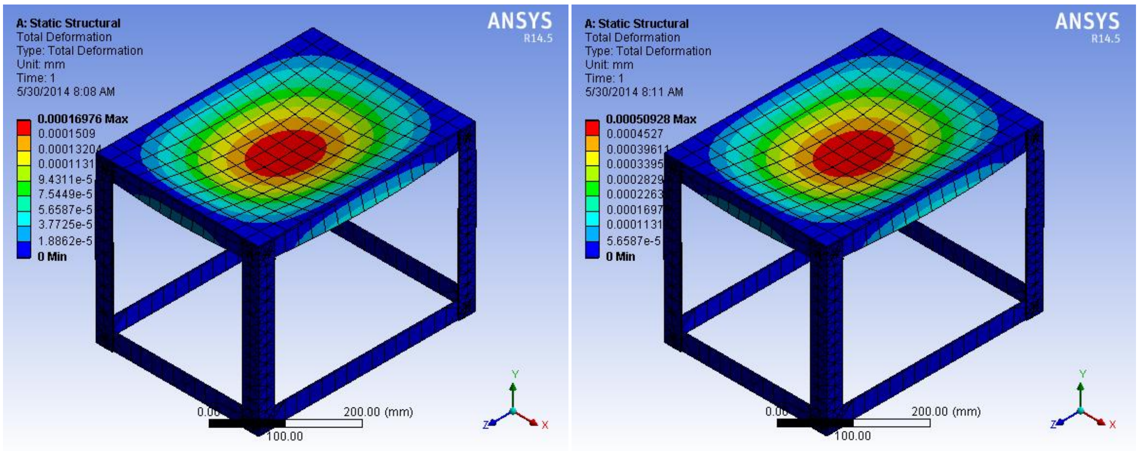


Fig.3. *Deformation under 0.5 kg load and Height 0.05 m and 0.15 m*

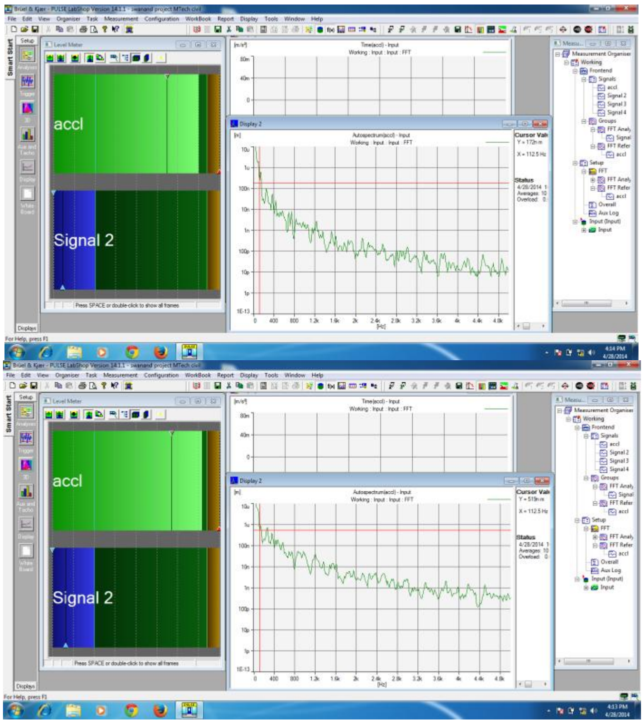


Fig.4. *Ansys results under 0.5 kg load and Height 0.05 m and 0.15 m*

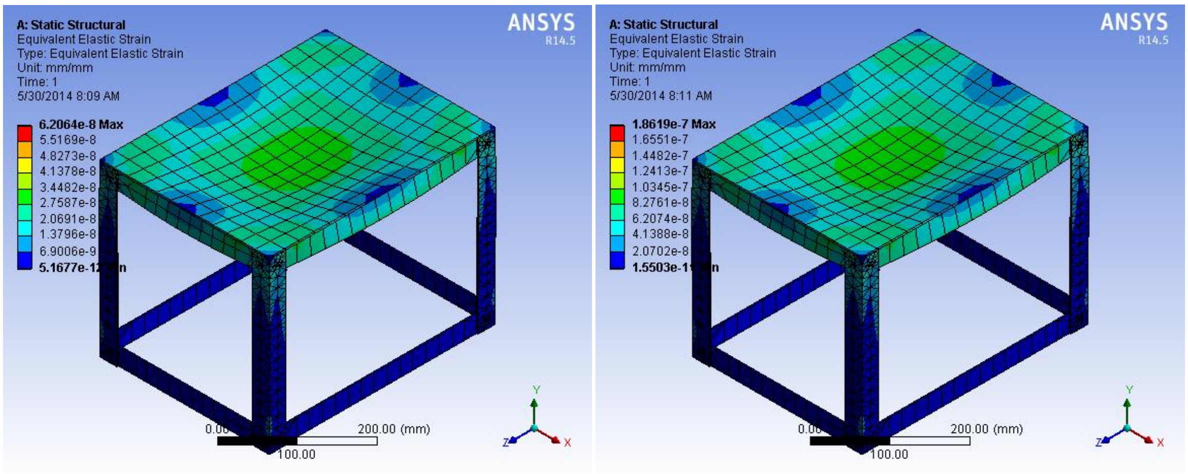


Fig. 5.*Equivalent elastic strain under 0.5 kg load and Height 0.05 m and 0.15 m*

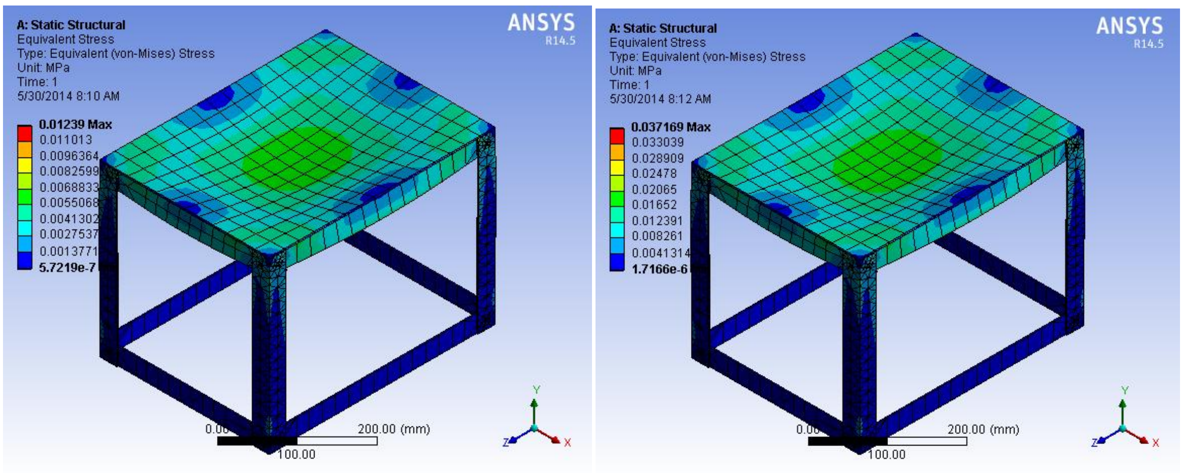


Fig. 6. *Equivalent elastic strain under 0.5 kg load and Height 0.05 m and 0.15 m*

4. CONCLUSIONS

1. The following characteristics of impact responses: the maximum impact load, the impulse, the duration of impact load, the maximum midspan deflection, and the time taken for the maximum midspan deflection increased as the drop height was increased. The duration of impact load, the maximum midspan deflection, and the time taken for the maximum midspan deflection were affected by the flexural rigidity of the Framed Structure.

2.An analytical model was developed to determine the maximum midspan deflection. The maximum midspan deflection is an important index for evaluating damage levels of RC beams subjected to impact loading. The analytical model was shown to be in good agreement with the experimental mid-span deflection when the RC beams exhibited only an overall flexural failure.

3. A simple overview of the stresses has been critically discussed regarding the standard factors affecting these structures under dynamic loading in which the stress is produced by tensile stress. In many load cases for models the dynamic loading applied to the wall in the ZZ direction acts perpendicular towards each model. When actually hitting the structure the impact pressure affecting the models leads to an increase of kinetic energy of the system producing larger velocity in each element. The higher velocity leads to movement of the elements resulting in large displacement of the structures.

4. According to the modeling result as explained in the above topics, the numerical simulation by using Ansys software could produce the result as closed as an experimental result. Furthermore, finite element analysis by using Ansys software is capable of developing reasonable and realistic estimations available in order to investigate the possible damage modes of reinforced concrete frame under impact loads.

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