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Modal Analysis of Shear wall with various Finite Elements and its Validation

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ABSTRACT
Shear walls are constructions meant to resist earthquakes to an extent Concrete and steel shear walls are being constructed in multi-storeyed buildings to lessen the effects (responses of the structure in terms of the motion parameters – displacement, velocity, etc.) in many parts of the world .Several examples of the Finite element modal analysis of shear walls is cited in the literature literature .But, many of them lie far away from predicting the experimental modal shapes of shear walls due to the limitations of the software and poor element shapes .Use of more refined mesh and higher order elements and some special treatments are suggested as possible solutions to bring the modal analysis close to the experimental results and some of the case studies. An attempt towards this direction using ANSYS software is the primary aim of this thesis. The objective of this thesis is to investigate the use of the finite element method for the analysis of reinforced concrete shear wall and evaluate the rate of convergence of elements
Keywords *- h-Refinement, L2 Error norm, Modal Analysis, Refined mesh, Shaking Table.*

I. INTRODUCTION

Reinforced concrete (R/C) shear walls are commonly used as the lateral load-resisting system of structures in zones of high seismic risk. Shear walls are widely used in medium to high rise buildings as these walls are very effective in providing resistance and stiffness against the lateral loads imposed by wind and/or earthquake. These walls also provide sufficient ductility and very good lateral drift control which prevent from the undesirable brittle failure against the strong lateral loads, especially during an earthquake.

Concrete and steel shear walls are being constructed in multi-storeyed buildings to lessen the effects (responses of the structure in terms of the motion parameters – displacement, velocity, etc.) in many parts of the world .shear wall buildings are considered to be earth quake resistant. Several reports indicate its good behavior in past earthquakes. On March 3, 1985, a magnitude 7.8 earthquake hit the central zone of Chile where most of the reinforced concrete buildings were located. Reconnaissance reports indicated extremely good seismic performance of these buildings, with very minor damage or no damage at all.

1.1 Shear wall

Shear walls are the walls that resist to wind or earthquake loads acting parallel to the plane of the wall in addition to the gravity loads from floors and roof adjacent to the wall. These walls provide lateral support for the rest of the structure and the lateral load are resisted mainly by flexural action of the vertical cantilever wall.

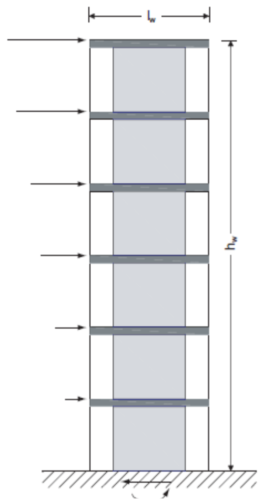

Fig.1 shear wall

1.2 Modal Analysis

A technique used to determine structure's vibration characteristics such as natural frequencies, mode shapes, mode participation factors (i.e., how much a given mode participate in given direction).Modal analysis is the most fundamental of all the dynamic analysis types. It allows the design to avoid resonant vibrations or to vibrate at a specified frequency .Also, gives the engineer an idea of how the design will respond to different types of dynamic loads.

II. ANSYS.10

Program ANSYS is capable of handling dedicated numerical models for the non-linear response of concrete under static and dynamic loading. ANSYS offers a comprehensive range of engineering simulation solution sets providing access to virtually any field of engineering simulation that a design process requires. ANSYS was used to model both the wall and the shaking table. The purpose of this selection was to benefit from the features of a special reinforced concrete element called SOLID65 [12].

2.1 ANSYS Finite Element Model

The specimen is a seven storey concrete shear wall (web wall and flange wall) made of a 3.65m wide web wall and 4.88m wide flange wall. The total height of the specimen is 19.96m. The building is the tallest structure ever tested on a shaking table. The web and the flange walls are fixed at the base. The web wall provides lateral resistance in the direction of loading. The thickness of the web wall and flange wall is 152mm.Experimental mode shapes have compared with finite element mode shapes.[1]

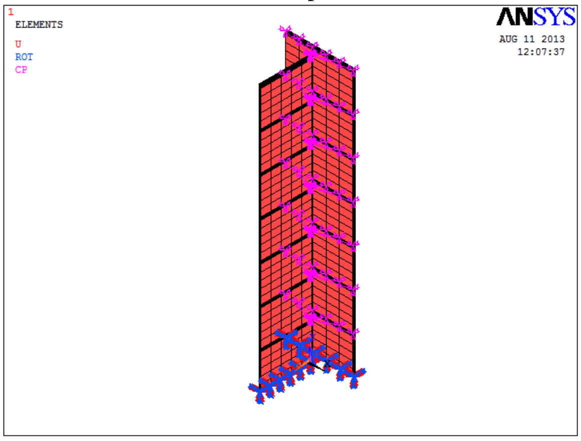

Fig. 2 Meshed model of shear wall

2.1 Analysis Type

The finite element model for this analysis is a shear wall under base excitations representing four earthquake records of increasing intensity. For the purposes of this model, the spectrum analysis type is utilized. To investigate the modal characteristics of the shear wall, a modal analysis was done first

TABLE 1 Comparison of frequencies obtained from modal analysis:

	Mode1 (Hz)	Mode2 (Hz)	Mode3 (Hz)
Model frequency (Ansys)	2.01	6.27	9.26
Experimental frequency	1.91	6.99	10.84

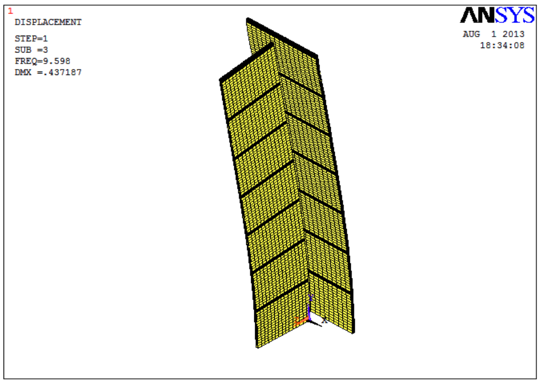

Fig. 3 Mode 3

III. SPECTRUM ANALYSIS

A spectrum analysis is one in which the results of a modal analysis are used with a known spectrum to calculate displacements and stresses in the model. It is mainly used in place of a time-history analysis to determine the response of structures to random or time-dependent loading conditions such as earthquakes, wind loads, ocean wave loads, jet engine thrust, rocket motor vibrations, and so on.

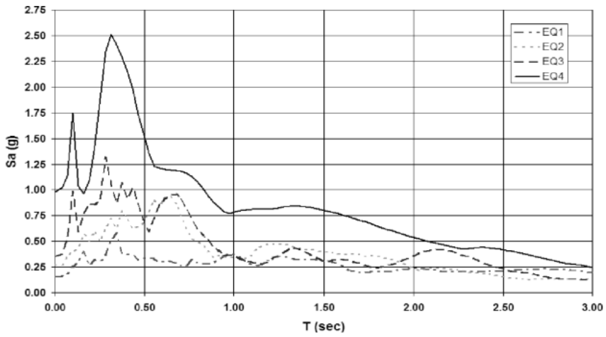

Fig.3 Earthquake input motions response spectra obtained from the 1994 Northridge earthquake record

The spectrum is a graph of spectral value versus frequency that captures the intensity and frequency content of time-history loads. As the specimen has been subjected to base excitations during the experiment, we have to provide this base excitation to the finite element model created in Ansys10.The above figure shows the acceleration spectra of the four input motions

TABLE 2.Spectral values obtained for EQ4 from the above spectra.

	Frequencies obtained	**Spectral values**
1	2.01	1.5
2	6.27	1.75
3	9.26	1.6

Then the spectrum analysis carried out .The result obtained from the spectrum analysis is the displacement due to the base excitations. The first three modes of most buildings exhibit cantilever-like deformation. Just as a cantilever deflects the most at the top, the displacements of the first three modes of a building are greatest at the highest level.

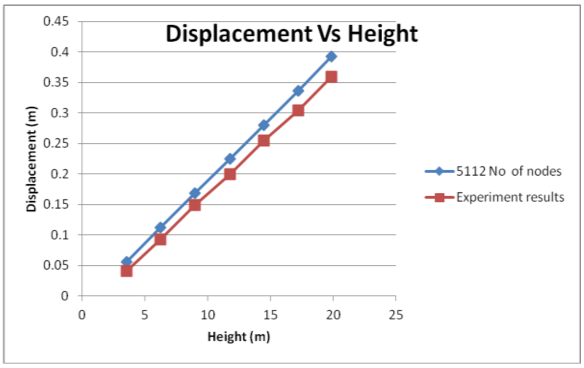

Fig.4 comparison of displacement (before h - refinement)

IV. MESH REFINEMENT

Convergence of finite element solutions with mesh refinements (i.e. more of the same kind of elements are used) is termed h-convergence. By refining mesh the no. of nodes increases from 5112 to 108032. As we refine the mesh, the domain is more accurately represented and therefore, the boundary approximation errors are expected to zero.

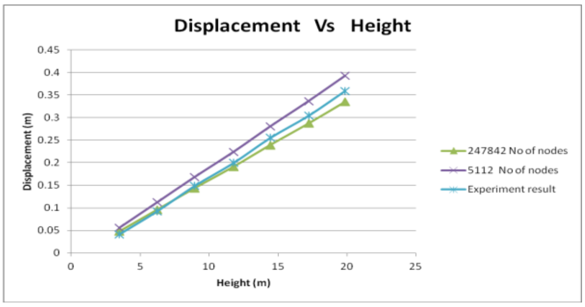

Fig.4 comparison of displacement (After h - refinement)

TABLE 3 Comparison of displacement before & after h- refinement

No. of nodes = 5112	**No. of nodes = 34122**	**No. of nodes = 108032**	**No. of nodes = 247842**	**Experiment**
0.0560	0.0479	0.0478	0.0478	0.041430
0.1121	0.9588	0.0957	0.0956	0.092322
0.1682	0.1438	0.1436	0.1434	0.148592
0.2243	0.1917	0.1914	0.1912	0.199988
0.2804	0.2397	0.2393	0.2391	0.255919
0.3365	0.2876	0.2997	0.2869	0.304438
0.4487	0.3835	0.3829	0.3825	0.393826

V. ERROR ESTIMATION

The main objective of this thesis is to find the error (E= u- u^a) between finite element solution and exact solution, also to provide possible solutions to bring the finite element solution close to exact results. Where u is the exact solution and u^a is the finite element solution. Therefore, the error in the approximation can be reduced either by reducing the size of elements or increasing the degree of approximation. Convergence of finite element solutions with mesh refinements (i.e more of the same kind of elements are used) is termed h-convergence

5.1 Relative L2 error norm

There are several ways in which we can measure difference (or distance) between any two functions u and u^a .The point wise error is the difference of u and u^a at each point of domain. More generally used measures or (norms) of the difference of two functions are the L2 norm and energy norm. For any square integrable functions u and u^a defined on the domain (a, b) ,the two norms are defined :

$$\text{Relative L2 error norm} = \frac{\| u\text{-}ua \|}{\| u \|} \tag{1}$$

$$\| U - U^a \| = \sqrt{\sum_{i=1}^{n} (U_i - U_i^a)^2} \tag{2}$$

$$\| U \| = \sqrt{\sum_{i=1}^{n} (U_i)^2} \tag{3}$$

Where u = exact solution

u^a = Finite element solution

TABLE 4. Error Estimation

Relative L2 error norm	
No.of nodes	Error norm(‖ e‖)
5112	0.0669
34122	0.060
108032	0.05955
247842	0.05937

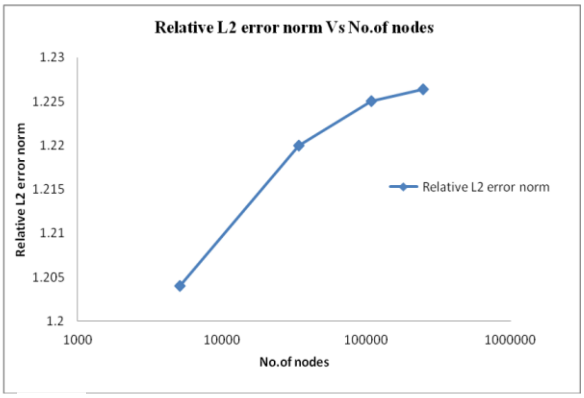

Fig. 5 Log –log plot of the L2 norm of errors versus mesh size

The log log plots give the rates of convergence in the norms.The rates of covergence are given by the slope of line.

VI. CONCLUSION

The following conclusions were arrived based on the analytical investigation conducted Shear wall,

In the present study, a seven storey RC shear wall subjected to base excitation has been analysed and compared with the experimental results. Final study was focussed on error estimation and to find the rate of convergence from Relative L2error norm Vs no. of nodes graph. The main objective of this thesis is to find the error (E= u- u^a) between finite element solution and exact solution Error estimates helps to give an idea of the accuracy of the approximate solution.

In order to bring approximate solution close to exact solution, h-refinement will be a possible solution. From the L2 error Vs mesh size graph, it is clearly understood that, the error goes decreasing as the no. of nodes increases .The prediction of the behaviour of shear walls such as displacement, bending moment, shear force etc using FEM, will be in good agreement with exact behaviour.

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