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Vibration Analysis of Multi Storey Buildings In Staad Pro

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***Abstract*- A major trust of modal parameters identification (MPI) research in recent years has been based on using artificial and natural vibrations sources because vibration measurements can reflect the true dynamic behavior of a structure while analytical prediction methods, such as finite element models, are less accurate due to the numerous structural idealizations and uncertainties involved in the simulations. This paper presents a state-of-the-art review of the time-frequency techniques for modal parameters identification of civil structures from acquired dynamic signals as well as the factors that affect the estimation accuracy. Further, the latest signal processing techniques proposed since 2012 are also reviewed. These algorithms are worth being researched for MPI of large real-life structures because they provide good time-frequency resolution and noise-immunity.**

***Keywords*- modal parameters identification, time-frequency algorithms, wavelet transform, synchrosqueezing transform, civil structures, dynamic excitation sources.**

I. INTRODUCTION

Excessive floor vibrations have become a greater problem for the occupants. These issues had become one of the most significant challenges produces by the traffic and occupants. Structure-borne sound and vibrations from traffic in dense urban environments can cause annoyance to the inhabitants of surrounding buildings besides being disruptive to the operation of manufacturing facilities, medical facilities, and research laboratories. Individuals can detect building vibration values that are well below those that can cause any risk of damage to the building or its contents. In addition, soil structure interaction is certainly a typical subject but nevertheless still new in it applicative aspects. The interaction may leads to an increment of the fundamental period of the structure compared to the fixed-base solution. In this study, the 3D finite element model in LUSAS was developed to perform the vibration analysis on the interaction of structure and foundation.

1. Reviews on Ground Vibration Theory:

Some common sources of ground-borne vibration are trains, buses on rough roads, and construction activities such as blasting, pile-driving and operating heavy earth-moving equipment:

- Ground borne vibration can be a serious concern for nearby neighbour of a transit system route or maintenance facility, causing buildings to shake and rumbling sounds to be heard. It is unusual for vibration from sources such as buses and trucks to be perceptible, even in locations close to major roads. The vibration being produced by the traffic propagated through the foundation of the floors and walls of a building will create resonance frequencies to the building. Hence, it will produce perceptible vibration, rattling of items such as windows or dishes on shelves, or a rumble noise. This will create the room surfaces act like a giant loudspeaker causing so called ground-borne noise. It will make the occupants in the building felt uncomfortable with the sounds in the room. Ground borne vibration is a creation of man-made over decade ago due to the developments of road, highway and rail networks. Vehicles move on the road and the train on the railways will produce vibration to the ground. The vibration will propagate through the ground and into buildings, resulting in uncomfortable vibration and unacceptable levels of noise in the building. This is clearly investigated at the Wellington Hospital in London.

- The building lies directly above two mainline railway tracks and within only a few metres of four underground railway tunnels and the main road. The problem related to this matters are the multiples sources of vibration produced by the train and cars propagates along the surfaces of the ground, and influenced the internal noise and vibration.

2. Natural Frequency Analysis:

- The end results of the modal analysis by LUSAS were produced tenth modes with the natural frequencies and maximum deflection of each mode. The first mode of the structure with rigid base obtained the natural frequency of 1.203 Hz and the maximum deflection is 0.047mm as shown in the (a), while the first mode of structure considering the soil underneath the building.

- The natural frequency of 0.7850x10-5 Hz and the maximum deflection is 0.04235 mm as shown The other values of natural frequency and maximum deflection from mode 1 until mode 10 are shown .
- It can be seen that the natural frequencies are decreased when the structure is modelled considering the soil underneath the building. It shows that the influence of interaction between the structure and the foundation system produce the stiffer structure due to the mass is also increased.
- This is also due the combined effect of translational and rotational simulating soil deformability as stated by Ceroni . The effect cannot be neglected; however it depends on the characteristics of the structure itself including stiffness, height and also the foundation of soil properties.

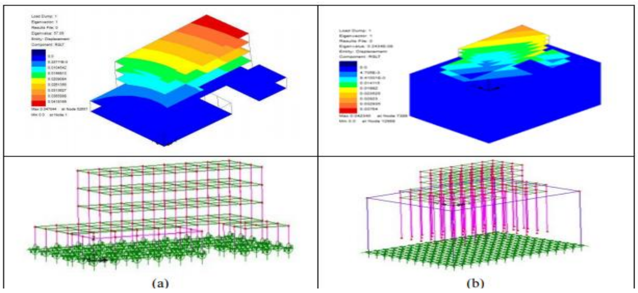


Figure. 1. (a) Mode shape of the structure with rigid base, (b) Mode shape of the structure with considering the soil underneath the building.

II. OBJECTIVE

Analyzing the frame both statically and dynamically using the matrix approach of FEM by developing generalized codes in **STAAD PRO**.

To find the natural frequency of the structure along with the various other parameters.. To compare the static and dynamic analysis.

1. Theoretical and Finite Element Formulation:

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.

1.1. Static Analysis of Frame:-

A plane frame can be defined as connection of bars or framework of bars which are connected in a same plane rigidly. A frame experiences reactions at various supports along with deflection, when it is subjected to a load or moment at various nodes. As the effect of the deflections induced, internal forces are induced in the frame bars. The analysis of frame comprises of determination of all these values.

2. Use of Matrices:

While solving the problems we have observed that many simultaneous equations are formed to express the equilibrium and force displacement, which are solved with the help of series of substitution. This can be done more conveniently with the help of matrices and it has a distinct advantage in MATLAB environment as it can be expressed easily using arrays. For the analysis of frame, the general notation used is,

[F]= [K][U] Where, [F] is the force matrix is the stiffness matrix.

III. LITERATURE REVIEW

T N T Chik , M F Zakaria , M A Remali and N A Yusoff "Vibration Response of Multi Storey Building Using Finite Element Modelling" Interaction between building, type of foundation and the geotechnical parameter of ground may trigger a significant effect on the building. In general, stiffer foundations resulted in higher natural frequencies of the building-soil system and higher input frequencies are often associated with other ground. Usually, vibrations transmitted to the buildings by ground borne are often noticeable and can be felt.

It might affect the building and become worse if the vibration level is not controlled. UTHM building is prone to the ground borne vibration due to closed distance from the main road, and the construction activities adjacent to the buildings. This paper investigates the natural frequency and vibration mode of multi storey office building with the presence of foundation system and comparison between both systems. Finite element modelling (FEM) package software of LUSAS is used to perform the vibration analysis of the building. The building is modelled based on the original plan with the foundation system on the structure model.

The FEM results indicated that the structure which modelled with rigid base have high natural frequency compare to the structure with foundation system. These maybe due to soil structure interaction and also the damping of the system which related to the amount of energy dissipated through the foundation soil. Thus, this paper suggested that modelling with soil is necessary to demonstrate the soil influence towards vibration response to the structure.

Regina Sampaio, Remo Magalhaes De Souza "Vibration Analysis of a Residential Building'' The aim of this paper is to present the results of a study regarding vibration problems in a 17 storey residential building during pile driving in its vicinity. The structural design of the building was checked according to the Brazilian standards NBR6118 and NBR6123, and using commercial finite element software. An experimental analysis was also carried out using low frequency piezo-accelerometers attached to the building structure. Structure vibrations were recorded under ambient conditions. Four monitoring tests were performed on different days. The objective of the first monitoring test was an experimental modal analysis.

Ehsan Esna Ashari "Calculating Free and Forced Vibrations of multi-story Shear Buildings by Modular method" The present study discretizes and calculates free and forced vibrations of a multi-story building by shear model. The present study shows that for free vibrations a dynamic system becomes a static system; as a result, static theories of linear structures can be used. Then, frequencies and modular forms are calculated. By contribution of Betti's corresponding displacement theorem, orthogonal characteristic of modules is characterized.

For forced vibrations, employment of module converts multidegrees free engaged dynamic system to several independent single degree free dynamic systems in each of which mass, spring stiffness and forced force for new system are linear combinations of mass, spring stiffness and forced force of engaged system. For example, frequencies, modular forms and forced displacement from transverse load to story such as hurricane force and acceleration imposed on building foundation, say earthquake, are manually calculated and compared by simulating with commercial-research software package, STAAD PRO. Results from STAAD PRO for forced vibrations are more accurate that results from approximate method of SAP 2000.

Rajmane Ashvini M "Determination Of The Fundamental Period Of Vibration Of Multi-Storey Rc Buildings" The period of vibration is the important parameter in the design of buildings as it governs the effect of earthquake. To design any building firstly fundamental period of vibrations is calculated. By using fundamental period of vibration spectral acceleration is calculated and then base shear is calculated. Many design codes provide simple empirical relationship relating the fundamental period of vibration of a building to its height. These relationships conservatively estimate the period of vibrations and consequently the resulted base shear force will be conservatively predicted. For the analysis of multi-storey reinforced concrete buildings ETABS software is used.

IV. CONCEPT OF VIBRATION GENERATION

The approach and accuracy of the analytical results depends on the idealization of the geometry and loading of the structure. In the present context, the wind load coefficient are computed using the provisions from relevant IS-875(Part-3): 1987. The symmetrical bare frame with known spacing is then performed with modal analysis using the method of reduced mode extraction which is to be preceded by mode-superposition harmonic response analysis on the lumped mass shear beam model to compute the displacements at the all sixteen nodes by considering the wind load as sinusoidal in along-wind direction. The response is then to be evaluated using the FE software package STAAD PRO.

1. Single Degree of Freedom Ystems:

In this system, if the mass *M* were displaced from its equilibrium (rest) position and then released, its displacement *y* plotted against time *t* would represent a sine wave. In the absence of damping, this motion would continue indefinitely, with the peak displacement corresponding to the initial release position. The time taken to complete each cycle would depend only on mass *M* and spring stiffness *k* of the system. In practice, all vibrating systems encounter a degree of damping. This is represented in the SDOF model by the dashpot damper. As an alternative to displacing and then releasing the mass, the vibrations could be initiated by subjecting the mass to a dynamic (time varying) load. This is represented in the model by the external force *p(t)*. The motion of the SDOF system can be defined in terms of three parameters:

- Frequency
- Amplitude
- Damping.

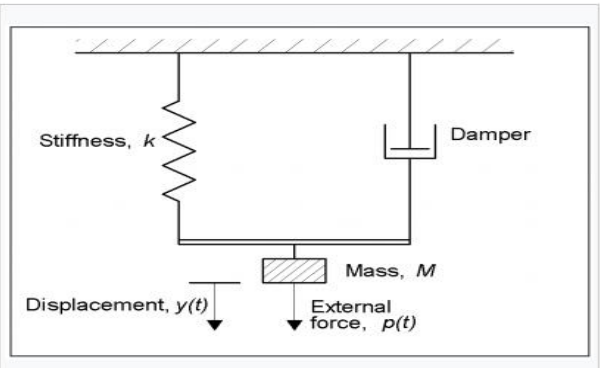


Fig. 2. {a} Single degree of freedom systems.

The frequency of a system, or of an applied force, is a measure of the rate at which the system vibrates. The frequency is normally quoted in Hertz (cycles per second) or alternatively in radians per second and is proportional to the square root of the stiffness *k* divided by the mass *M*. The inverse of the frequency *f* is the period *T*, defined as the time taken for the system to complete one whole cycle.

2. Discrete Wavelet Transform

The wavelets are mathematical relations that examine the data corresponding to the resolution or scale . They help in the study a signal at distinct resolutions in distinct windows. For example, if the signal is visualized in a prominent window, the gross characteristics may be noticed, but if they are visualized in a smaller window, only small items can be noticed.

The wavelets offer certain advantages compared to Fourier transforms. For example, they are doing a good job in the estimation of signals having discontinuities with high spikes. The wavelets can also model the music, speech, music, non-stationary stochastic signals and video. The wavelets may be used in applications such as human vision, turbulence, vibrational signal compression, earthquake prediction and radar etc .

The term "wavelets" is utilized to designate a set of basic functions of orthonormal produced by a mother wavelet ψ and translation of scaling function ϕ and dilation . The scale of representation of multi-resolution discrete function can be called as a Discrete Wavelet Transform . Discrete Wavelet Transform is a quick linear operation on a vector of data, whose length is an integer power of 2. This conversion is orthogonal and invertible, where the inverse transform showed as a transpose matrix is the transform matrix. The basis of wavelets or function, different cosine and sines as in Fourier Transform, are well localized in space. However similar to cosines and sines functions, independent wavelets are localized in frequency.

The wavelet or orthonormal basis is characterized as

$$\psi_{(j,k)}(x) = 2^{j/2}\psi(2^j x - k)$$

The scaling function is specified as

$$\phi_{(j,k)}(x) = 2^{j/2}\phi(2^j x - k)$$

Where ψ the wavelet functions and j is integers that scale the wavelet function and k is integers that dilate the wavelet function. The wavelet equation, in terms of the wavelet coefficients is

$$\psi(x) = \sum_k^{N-1} g_k \sqrt{2\phi(2x-k)},$$

$$k = 0,1,2, \ldots \ldots \ldots . . N-1$$

Where g_k is high pass wavelet coefficient.

The scaling equation is defined in terms of the scaling coefficients as

$$\phi(x) = \sum_k^{N-1} h_k \sqrt{2\phi(2x-k)}$$

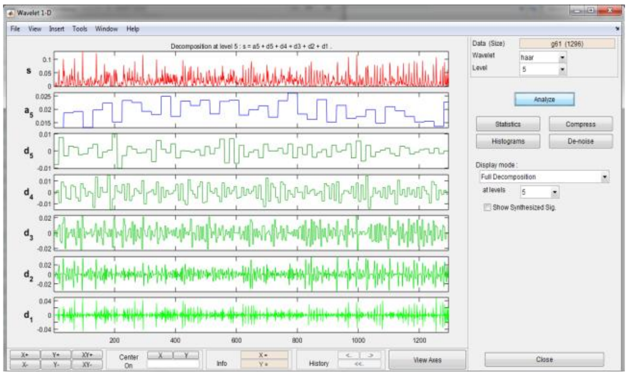
Where $\phi(x)$ is scaling function and h_k is low pass scaling coefficients. The scaling and wavelet coefficients are associated by the quadrature mirror relation , hence

$$g_n = (-1)^n h_{1-n+N}$$

Where N is the number of vanishing moments , Figure 5.1 shows that the graphical illustration of Discrete Wavelet Transform is

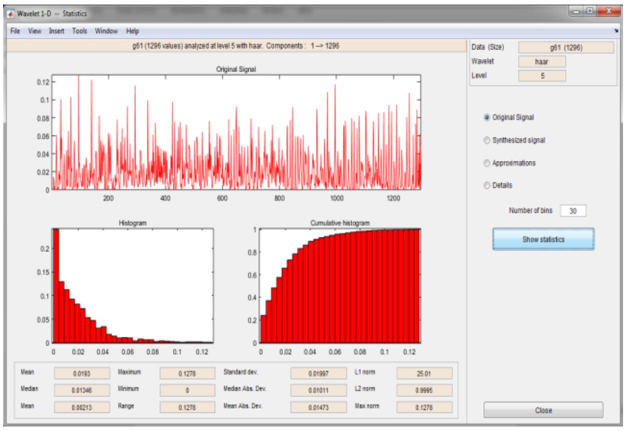
V. RESULTS AND SIMULATIONS

1. Vibrational Signal Analysis:



Data (Size) g61 (1296)
Wavelet haar
Level 5
Display mode : Full Decomposition
at levels 5

Fig. 3. DWT vibrational signal detection in multistory building.

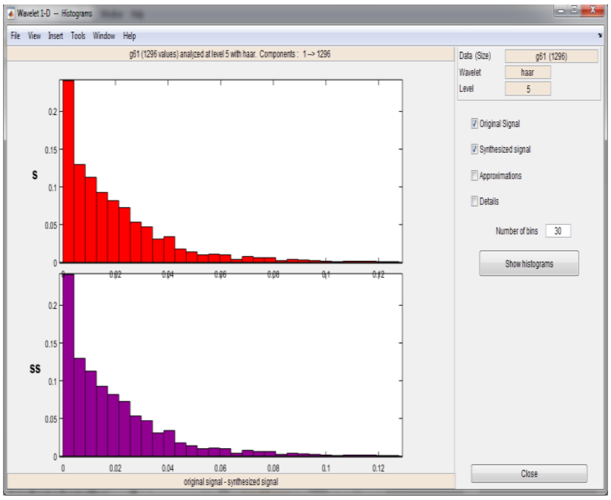


g61 (1296 values) analyzed at level 5 with haar. Components : 1 --> 1296

Data (Size) g61 (1296)
Wavelet haar
Level 5
Number of bins 30

Mean	0.0193	Maximum	0.1278	Standard dev.	0.01997	L1 norm	25.01
Median	0.01346	Minimum	0	Median Abs. Dev.	0.01011	L2 norm	0.9995
Mean	0.00213	Range	0.1278	Mean Abs. Dev.	0.01473	Max norm	0.1278

Fig. 4. DWT vibrational signal detection in multistory building statics.



g61 (1296 values) analyzed at level 5 with haar. Components : 1 -> 1296

Data (Size): g61 (1296)
Wavelet: haar
Level: 5
Number of bins: 30

original signal - synthesized signal

Fig. 5. Vibrational histogram curve.

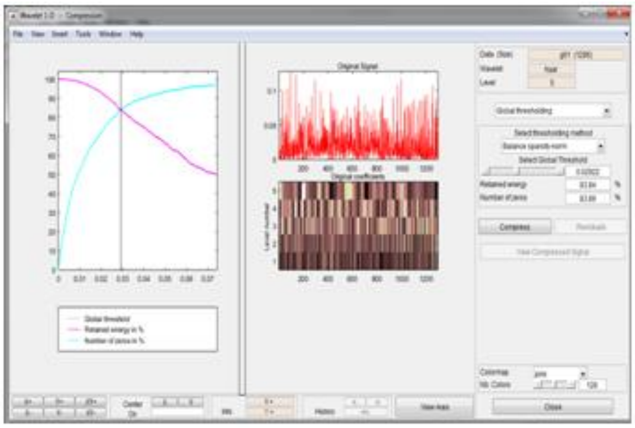
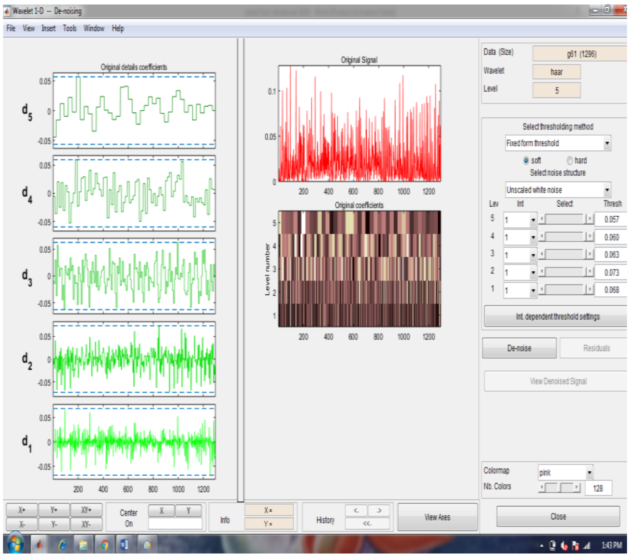


Fig. 6. Vibrational signal compression.



Data (Size): g61 (1296)
Wavelet: haar
Level: 5

Select thresholding method: Fixed form threshold
● soft ○ hard
Select noise structure: Unscaled white noise

Lev	Int	Thresh
5	1	0.057
4	1	0.060
3	1	0.063
2	1	0.073
1	1	0.068

Colormap: pink
Nb. Colors: 128

Fig. 7. De-noising vibrational signal.

VI. CONCLUSIONS

The maximum particle velocity increased to the 2rd floor; attenuation occurred in the 2th floor. The particle velocity in the *z*-direction was the largest, and it should be paid attention. The dominant frequency of the building showed a trend from high frequency to low frequency, the duration became short and the acceleration decreased to the 2th floor.

The dominant frequency domain of the building became smaller and gradually concentrated to the low-frequency domain to the 2th floor. The response signal of the building to the blasting vibration was widely distributed in the frequency domain, but its main frequency band was basically between 0 and ∼140 Hz. With the increase in the building floor, the high-frequency particle velocity gradually decreased, gathered to the low frequency, and developed from the dispersed multiband to the concentrated low-frequency band. This trend was evident in the *z*-direction. There were multiple peaks in the vibration velocity of each direction with the frequency band distribution, and the frequency domain corresponding to the peak was dispersed.

The energy of the building's response to the blasting vibration was between 0 and 171.6 Hz. The frequency domain corresponding to the dominant energy generated by the vibration of the building developed to the low frequency. Moreover, the higher the floor, the higher the low-frequency energy, the more concentrated for the frequency domain of the low frequency. In the low-frequency band, not only the energy value but also the energy increased toward the low frequency.

Two different wavelet-based damage detection approaches were evaluated using experimental and simulated data. One of the approaches is based on the tracking of frequency shifts using the continuous wavelet transform (CWT) while the second approach is aimed to identify singularities in the high frequency component of the structural response via the Fast Wavelet Transform (FWT). Based on the results obtained the following conclusions/recommendations are drawn:

1. Wavelet transform

It was found that selection of appropriate wavelet parameters is critical for a successful analysis of the signal via CWT. Wavelet parameters should be selected based on the expected frequency content of the signal and desired time and frequency resolutions. When clean toy signals and appropriate wavelet parameters are used, the performance of the CWT for frequency tracking is ideal. Identification of frequency shifts via ridge extraction of the Wavelet Map was successful in most of the experimental and numerical scenarios investigated. Moreover, the frequency shift can be inferred most of the time but the exact time at which it occurs is not that evident.

2. Fast wavelet transform

Fast Wavelet Transform analysis of the high frequency response of the structure to detect singularities induced by damage episodes was shown to be successful only at low levels of noise scenarios. Moreover, if the noise amplitude is larger than the discontinuity caused by the damage, the spike related to the damage episode will get imbedded within the noise in the signal. In the numerical model the amplitude of the FWT spikes was found to be related to the level of damage and the proximity of the sensor to the location were the damage was induced. Such correlation was not found on the experimental test, however, notice that this may be due the reduced scale nature of the setups employed. Other studies using large scale shake table test data of reinforced concrete columns have found that the discontinuity produced when a reinforcing bar fails during an earthquake is large enough to be detected via FWT.

It must be noticed that for testing convenience, in the two experimental setups analyzed in this work the damage scenario (mass added/removed) differs from what is usually expected in an actual structure (stiffness degradation). However, the resulting effects in the dynamic response of the structure are of the same nature, i.e. a shift in the natural frequencies of vibration. Moreover, all of the cases analyzed (experimental and numerical) a sudden damage scenario is recreated (typical for example of a shear failure), in the case were damage evolves slowly a discontinuity at high frequencies is not likely to occur, but the natural frequencies shift can still be tracked.

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