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# Seismic Response Damage of Nuclear Tower

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## ABSTRACT

The seismic response of the nuclear tower is analyzed by investigating the frequency response during the main recorded events. The dynamic characteristics of the nuclear tower under seismic response with higher intensity are pointed out the dominant seismic time history components determines the response characteristics of the tower.

The nuclear tower coupled with the seismic loadings will amplify the damages to the structure. These results are consistent with field observations after major seismic response, this explains the symmetry of the nuclear tower damage during seismic response.

Seismic resistance measures, such as viscous damping or energy dissipation, dynamic properties and nuclear tower vibration elements will help to increase the accuracy of the life model. In this paper, improvement in using computing program and mathematical algorithms will increase both the accuracy and confidence of the results.

The contact problem of the nuclear tower structure is another direction for a detailed understanding the mechanism of the nuclear tower structure interaction, such as mode shapes, eigenvalues/vectors, deformation, propagation and non-propagation of cracks, and the stresses slip of the foundation caused by random seismic loading that can lead to damage. This study is helpful for designing new seismic resistant nuclear towers structures to reduce damage.

**Keywords** seismic, fatigue, random vibration, nuclear power plants

# اضرار الاستجابة الزلزالية لبرج نووي

## الخلاصة

تم تحليل الاستجابة الزلزالية لبرج نووي من خلال التحقق من تردد الاستجابة للبرج أثناء الظروف الرئيسية المسجلة للترددات .ان الخصائص الديناميكية للبرج النووي تحت ظروف الاجهادات العالية للاستجابة الزلزالية تشير الى انه سيادة مكونات مسار زمن الاستجابة يحدد خصائص الاستجابة للبرج .حالة البرج النووي مقرونة بالاحمال الزلزالية يودى الى تسريع الأضرار التي تلحق بهيكل البرج .هذه النتائج تتوافق مع مجال واضح بعد الاستجابة الزلازلية الكبرى وهذا يفسر تناظر اضرارالبرج النووي خلال الاستجابة الزلزالية. ان مقياس الحالات الخاصة لمقاومة الزلازل، مثل التخميد اللزج أو تبدد الطاقة، والخصائص الديناميكية واهتزاز اجزاء البرج النووي تساعد على زيادة دقة حساب عمر النموذج .أيضا، في هذا البحث التحسن في استخدام البرامج

الحاسوبية والخوارزميات الرياضية ساعدت في زيادة كل من الدقة والثقة في ايجاد النتائج . ان المشكلة التي تم دراستها في هذا البحث لهيكل البرج النووي هو اتجاه آخر لفهم مفصل لآلية للتفاعل مع هيكل البرج النووي ، مثل النسوق ، والترددات الطبيعية، التشوه، والنمو وعدم النمو للشقوق ، والاجهادات الانزلاقية للأساس الناتجة من الاحمال الزلزالية العشوائية يمكن أن تؤدي إلى أضرار . هذه الدراسة مفيدة لتصميم هياكل جديدة للابراج النووية مقاومة للزلازل وللحد من الضرر.

**كلمات مرشدة:** الزلزالية ،الكلل،الاهتزازات العشوائية،محطات القدرة النووية

## Nomenclature

| | | |
|---|---|---|
| A | Cross-sectional area | ($mm^2$) |
| $\sigma_{ijk}$ | Stress tenser | ($N/mm^2$) |
| $\lambda$ , $\mu$ | Lam´e parameters | |
| $\delta_{ij}$ | Kroniker delta | |
| $e_{ij}$ | Strain tenser | |
| $\partial_i$ | Derivative | |
| $u_j$ | Displacements | (mm) |
| $\nabla$ | Nabla | |
| $\phi$ | Scalar potential energy | |
| $\Psi$ | Vector potential energy | |
| $t$ | Time | (sec) |
| [A], [M], [C] | Matrices of pliancy, masses and damping. | |
| $U$, Ů *and* Ü | Vectors of acceleration of velocities and travels | |
| $\ddot{Q}$ | Vector of seismic impact acceleration | |
| $q(t)$ | Generalized coordinates | (mm) |
| $u(x,t)$ | Deflection at any point x | (mm) |
| $\phi_j(x)$ | Normal modes | |
| $S(f)$ | Power spectral density function | ($N^2/Hz$) |
| $R(\tau)$ | Autocorrelation function | ($N^2/Hz$) |
| $\tau$ | Period | (sec) |
| $u_{ijk}(t)$ | Standard deviations of the seismic response | (mm) |
| $\zeta$ | Damping ratio | |
| $\Omega$ | Excitation | (rad/s) |
| $u_{ijk}^2(t)$ | Variance of the seismic response | ($mm^2$) |
| $k$ | Stiffness matrix | (N/m) |
| $\phi_{ij}$ , $\phi_{id}$ | Eigen vectors | |

| | | |
|---|---|---|
| $\beta_i$ | Structural damping | (N.sec/mm) |

## INTRODUCTION

Conventional anti-seismic approach relies on the inertial-resisting capacity of the structure against earthquakes through a combination of properties such as strength, deformability and energy absorption. Damping the inherent energy dissipation capacity of such structure is very low (< 5 %). Very small part of energy is dissipated through elastic behaviour. Under strong seismic excitation, these structures deform beyond the elastic limit, forming localised plastic hinges, resulting in localised damage, and thereby absorption of seismic energy. [1]

Earthquake magnitude is a measure of the strength of the earthquake as determined from seismographic observations. Magnitude is essentially an objective; quantitative measure of the size of an earthquake. The magnitude can be expressed in various ways based on seismographic records (e.g., Richter Local Magnitude, surface Wave Magnitude, Body Wave Magnitude, and Moment Magnitude). Currently, the most commonly used magnitude measurement is the Moment Magnitude (M) which is based on the strength of the rock that ruptured the area of the fault that ruptured, and the average amount of slip. Moment is a physical quantity proportional to the slip on the fault times the area of the fault surface that slips; it is related to the total energy released in the earthquake. The moment can be estimated from seismograms (and from geodetic measurements). The Moment Magnitude provides an estimate of earthquake size that is valid over the complete range of magnitudes, a characteristic that was lacking in other magnitude scales, such as the Richter scale.[2]

Earthquake is one of the most destructive natural hazards. They may occur at any time of the year, day or night, with sudden impact and little warning. They can destroy buildings and infrastructure in seconds, killing or injuring the inhabitants. Earthquakes not only destroy the entire habitation but may de-stabilize the government, economy and social structure of the country. But what is an earthquake? It is the sudden shaking of the earth crust. The impact of an earthquake is sudden and there is hardly any warning, making it impossible to predict. [3]

After constructing the structural models, the seismic structural analyst should perform appropriate analyses to predict the earthquake response of the structure. Prediction of the earthquake response includes the selection of a method of analysis, formulation of structural mass and stiffness to obtain vibration properties, specification of damping, definition of earthquake loading and combination with static loads, and the computation of response quantities of interest. The analysis should start with the simplest method available and progress to more refined types as needed. It may begin with a pseudo-static analysis performed by hand or spreadsheet calculations, and end with more refined linear elastic response-spectrum and time-history analyses carried out using appropriate computer programs. [4]

The objective of this paper is execution of the basic static and dynamic calculation of twin cooling towers with the fans of propeller diameter 6 m for Oil Refinery. The basic static and dynamic analyses are based on the requirements of American standards for designing. The structure sizing was executed for limiting combination of static loading states including the actions of wind pressure. The designed quantities due to the action of seismic load in introduction of the structure ductility are lower than the actions of wind pressure. The design loads are compared and the dominance of particular loading states is assessed according to response internal forces caused by these loads in the structure. From this comparison it is explicitly evident that the temperature effects exert in the resultant design load combination the biggest influence upon the structure of the towers. A share of these temperature effects in total stress of the structure can be estimated as approx. 50%.[5]

Structures in nuclear power plants play a key role in mitigating the impact of earthquakes on the response of essential plant safety systems. The importance of structural components and systems in seismic damage mitigation is moreover amplified by the common cause-and-effect in which failure of a structure may lead to failure or loss of function of appurtenant mechanical or electrical components and systems. Therefore, when an earthquake occurs, the safety of structures in nuclear power plants has to be evaluated quickly and precisely in order to confirm the safety functions and keep a stable supply of electric power.. The seismic damage assessment system will make it possible to evaluate the damage level of the power plant structures in real-time immediately after seismic occurrence and analyse the current seismic resistance capacity. Containment structure constitutes a very important feature for the protection against radiation leakage, thus a seismic damage assessment system has been currently developed for the containment structure.

There have been considerable efforts to represent the damage level using damage indices capable of quantifying numerically the degree of damage. The concept of damage index can provide the means to quantify damage and relate it to costs and other consequences such as potential risk after earthquake. Hence, damage index can play an important role in retrofit decision-making and disaster planning in earthquake region. Although most of damage indices have been defined at member and structural levels, damage indices at finite element and structural levels are proposed in damage assessment method. This choice has been conducted by two reasons, the aim of assessment is in concern with the exact location of the heaviest damage in containment structures, and containment structures are not composed by distinct members but by shell elements [6].

Excitation techniques exist that will safely set the structures in motion, and measurement and instrumentation methods are available that will accurately record and analyze the resulting time-history response signals. A set of LLL computer programs was developed to extract the modal parameters from measured time-history response signals. These parameters can be used to validate or improve mathematical model B of the structure, or they can be monitored for changes that indicate degradation or change in the integrity of the structure. The computer programs have been analytically qualified and will be made available to the NRC for public use. The programs can be used for extraction of modal parameters from test data, or their qualification can serve as a benchmark for the evaluation of other computer programs [7].

Vibrations may be random in nature in a wide range of applications; however, such as vehicles traveling on rough roads or industrial equipment is operating in the field where arbitrary loads may be encountered. In these cases, instantaneous vibration amplitudes are not highly predictable as the amplitude at any point in time is not related to that at any other point in time. the lack of periodicity is apparent with random vibrations. The complex nature of random vibrations is demonstrated with a Fourier analysis of the random time–history, revealing that the random motion can be represented as a series of many overlapping sine waves, with each curve cycling at its own frequency and amplitude. With these multiple frequencies occurring at the same time, the structural resonances of different components can be excited simultaneously, thus increasing the potential damage of random vibrations [8].

## ADDITIONAL INFORMATION AND OTHER IMPORTANT DETAILS

Nuclear cooling towers are safe and durable structures if properly designed and constructed. Nevertheless, it should be recognized that this high quality level has been achieved only after the lessons learned from a series of collapsed or heavily damaged towers have been incorporated into the relevant body of engineering knowledge. While cooling towers have been the largest existing shell structures for many decades, their design and construction were formerly carried out simply by following the existing “recognized rules of craftsmanship”, which had never envisaged constructions of this type and scale. This changed radically, however, in the wake of the Ferrybridge failures in 1965 Fig. (1). On November 1st, 1965, three of eight 114mhigh cooling towers collapsed during a Beaufort 12 gale in an obviously identical manner. Within a few years of this spectacular accident, the response phenomena of cooling towers had been studied in detail, and safety concepts with improved design rules were developed [9].

The vibration response of a nuclear tower supported by a viscoelastic foundation with randomly loading along the nuclear tower is studied. The dynamic response of the nuclear tower consisting of the mean and variance of the deflection are obtained analytically in integral forms [10].

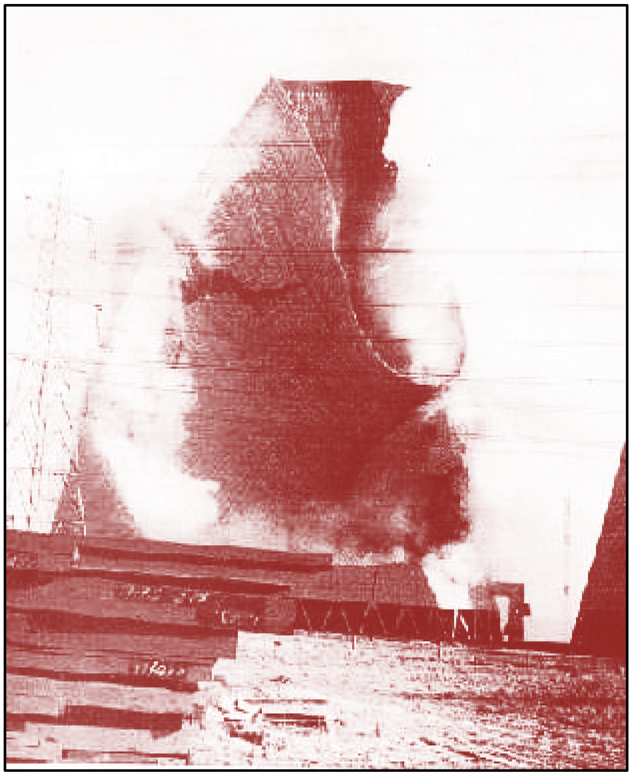

**Figure (1) Collapse of Ferry bridge Power Station shell [9]**

## FREQUENCY RESPONSE METHODS

This paper describe an approach for computing seismic response of nuclear tower damage or fatigue life directly from Seismic wave equation and the power spectral density of stress with respect to a time history. The stress power spectra density represents the frequency domain approach input into the fatigue. This function that describes how the power of the time signal is distributed among frequencies, mathematically this function can be obtained by using a Fourier Transform of the stress time history auto-correlation function and its area represents the signals standard deviation. It is clear that PSD is the representation of a random process.

A frequency analysis is carried out and the effect of the random loading on the response. It is found that the covariance functions of the stiffness have the modal shape function for the response. Furthermore, it is shown that in each frequency response there is a peak value for the frequency, which changes inversely with the load. It is also found that the peak value of the mean and also standard deviation of the deflection can be a decreasing or increasing function of the load speed depending on its frequency.

For nuclear tower structural system with many degrees of freedom seeking potential internal resonances and subsequently analyzing them can become very impractical. From an engineering viewpoint the alternative consisting in simulating the system numerically is very attractive employed linear modal analysis of nonlinear systems may completely overlook the occurrence of internal resonances forcing the engineer to ignore such occurrences Also one may end up using many more modes than are actually required to capture the dynamics of interest. It should also be realized that this methodology cannot detect all possible internal resonances between modelled and non-modelled modes [11, 12].

## SEISMIC RESPONSE CHARACTERISTICS

The response of any linear mechanical system to random excitation cannot be defined explicitly as a function to time; i, e. no equation for the response time history can be written as is possible for a deterministic forcing function. The response characteristics must be defined in terms of the statistical properties of a random process. The stochastic properties of a Gaussian process are described completely by the first two statistical moments. Moreover any realizable linear operation on a Gaussian random process yields another Gaussian random process. For random processes other than Gaussian more than the first two statistical moments are required to define the stochastic properties; and. linear operations usually change the random process. In contrast to a Gaussian process, the mathematics for non-Gaussian processes are generally much more complicated and complex or many practical problems. The random loadings acting on a structure can be described as a Gaussian process. If the structure is a linear time invariant mechanical system, then the resulting response also is a Gaussian random process. It is helpful. Therefore to review those basic statistical quantities that characterizes the structural response of linear, time invariant mechanical systems to Gaussian random excitation.

A simple observed time history record of any random physical phenomenon constitutes only one possible outcome from an infinitely large number of time history records which might have occurred. This collection of all possible records (called the ensemble) which might have occurred forms a random process which can be used to describe the random phenomenon of interest. For example each time history could represent the acceleration or stress time history measured at a distinct point on a flight vehicle structure. The collection of records would then represent the time histories measured at that same point for separate flights performed under identical conditions.

The statistical properties of the random process are computed by averaging over the ensemble at any instant of time Fig.(2), or by averaging over time on individual sample records. If the statistical properties found by averaging over the ensemble are invariant with respect to translations in time, then the random process is said to be stationary. If the random process is stationary and the ensembled averaged properties are numerically equal to the properties found by time averaging each individual record then the random process is said to be ergodic. Ergodicity therefore allows one to use the time averaged properties of an individual record to describe the properties of the entire random process.

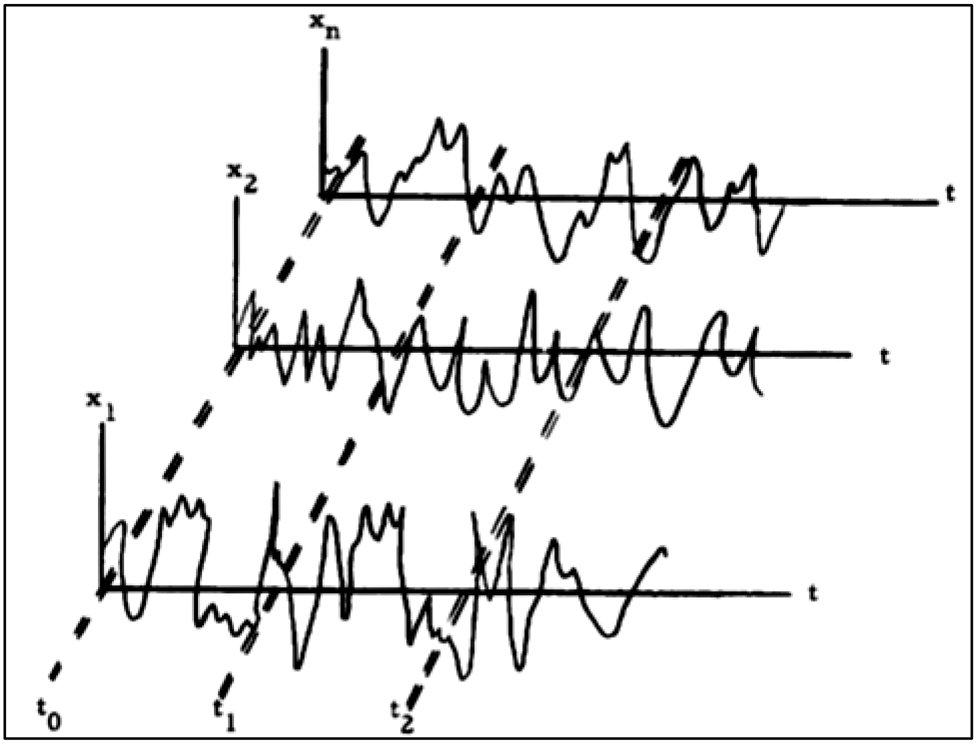

**Figure (2) Schematic representation of a seismic Process**

## MATHEMATICAL MODEL OF THE NUCLEAR TOWER

Nuclear tower power can be used to generate electricity. In addition, it is also used for the propulsion of military ships. To generate this type of power, governmental institutions and private organizations construct nuclear power plants.

To theoretically study a nuclear tower some forcing function must set the structure in motion. Because nuclear power plant structures are so massive, these forces must be large, which raises large forcing functions be physically realized or be applied to the structure safely, that is, without causing damage or otherwise lead to the damage of the tower of the plant, that have demonstrated experience in the field of testing large and massive structures. To ensure that the generation of power is safe, it is important to have ideas about the recommended nuclear tower dimensions.

## THE DIMENSIONS OF NUCLEAR TOWER

Every nuclear power plant should have a nuclear tower. The recommended overall height of the tower shown in Fig.(3) should be 160 to 162 meters. The overall height over basin level should be between 155 to 160 meters. The mouth diameter is 60 to 68 meters while the basin diameter is 100 to 117 meters. The height of the chimney is usually between 20 to 25 meters. The air outlet diameter is 70 meters to 75 meters. The cooling performance of the tower is 2500 megawatts.

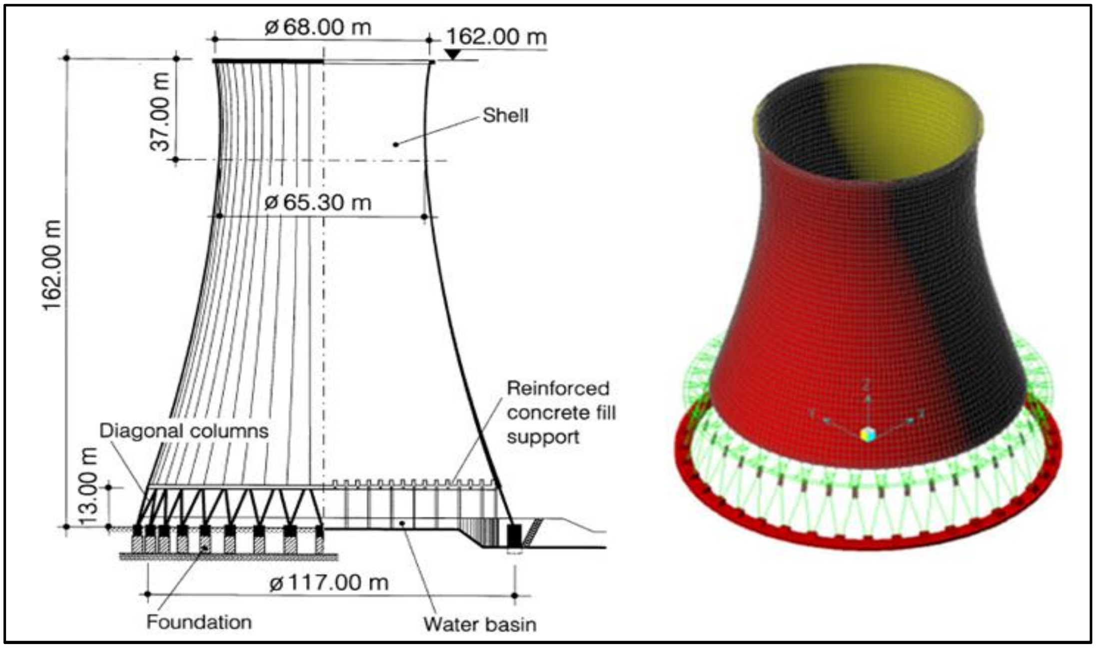

**Figure (3) Nuclear tower dimensions**

## THE SEISMIC WAVE EQUATION

Figure (4) show the time history of nuclear tower subjected to seismic excitation used in this paper.

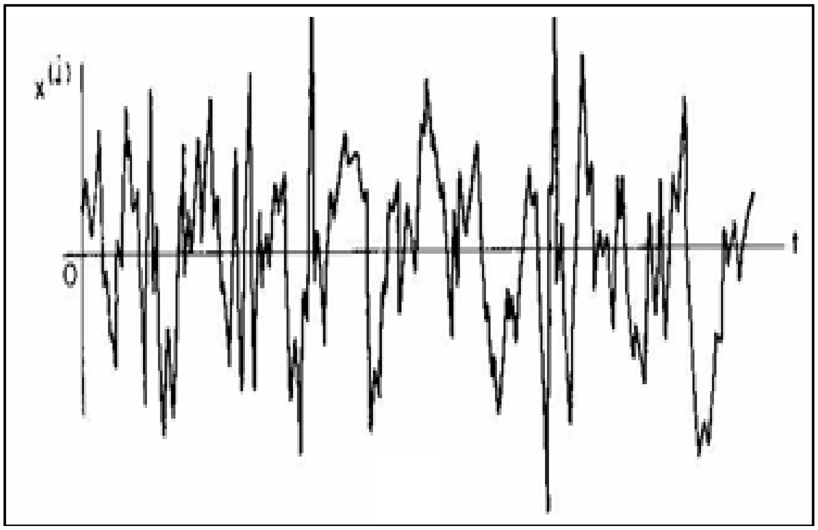

**Figure (4) Seismic time history**

The relationship between stress and strain can express in terms of the displacement u. Recall the linear, isotropic stress– strain relationship [10],

$$\sigma_{ijk} = \lambda\delta_{ij}e_{kk} + 2\mu e_{ij} \qquad \ldots(1)$$

where λ and μ are the Lam´e parameters and the strain tensor is defined as

$$e_{ij} = \frac{1}{2}\left(\partial_i u_j + \partial_j u_i\right) \qquad \ldots.(2)$$

Substituting for $e_{ij}$ in (1), we obtain

$$\sigma_{ijk} = \lambda\delta_{ij}\partial_k u_k + \mu\left(\partial_i u_j + \partial_j u_i\right) \qquad \ldots(3)$$

The displacement u is often expressed in terms of the wave scalar potential energy and wave vector potential energy Ψ, using the Helmholtz decomposition theorem

$$u = \nabla\phi + \nabla \times \Psi, \;\; \nabla.\Psi = 0 \qquad \ldots(4)$$

Then

$$\nabla.u = \nabla^2\phi \qquad \ldots..(5)$$

and

$$\nabla \times u = \nabla \times \nabla \times \nabla \times \Psi \qquad \ldots\ldots(6)$$

using the vector identity

$$\nabla \times \nabla \times u = \nabla\nabla.u - \nabla^2 u \qquad \ldots..(7)$$

then

$$\nabla \times u = \nabla\nabla.\Psi - \nabla^2\Psi$$
$$= -\nabla^2\Psi \qquad \ldots\ldots(8)$$

since $\nabla.\Psi = 0$

Now consider seismic excitation propagating in the three directions. The vector Potential becomes

$$\Psi = \Psi_x\left(t - \frac{x}{\beta}\right)\vec{X} + \Psi_y\left(t - \frac{x}{\beta}\right)\vec{Y} + \Psi_x\left(t - \frac{x}{\beta}\right)\vec{Z} \qquad \ldots..\;(9)$$

The displacement is

$$u_x = (\nabla \times \Psi)_x = \partial_y \Psi_z - \partial_z \Psi_y = 0 \qquad ..\ (10)$$

$$u_y = (\nabla \times \Psi)_y = \partial_z \Psi_x - \partial_x \Psi_z = 0 \qquad ..(11)$$

$$u_z = (\nabla \times \Psi)_z = \partial_x \Psi_y - \partial_y \Psi_x = 0 \qquad ....(12)$$

The motion is in the y and z directions, perpendicular to the propagation direction. The motion is divided into two components: the motion within a vertical plane through the propagation vector and the horizontal motion in the direction perpendicular to this plane, the motion is pure shear without any volume change (hence the names shear waves). Particle motion for a harmonic shear wave polarized in the vertical direction

## Stochastic approach

The nuclear tower model used in this study are multi-degree of freedom plane linear and nonlinear models, as shown in Fig (2).The nuclear tower is excited by seismic vibrations are assumed to be known stochastic processes resulting from the randomly profiled road.

Seismic analysis needs the following:

1- Mathematical modeling of oscillations.

2- Solution of the tasks of dynamic analysis, response spectrum analysis.

3- Damping.

The equation of motion of mathematical used in this study model is described by an equation of matrix type [13]:

$$[A][M]\ddot{U} + [A][C]\dot{U} + U = [A][M]\ddot{Q} \qquad .... \quad (13)$$

Where $[A], [M], [C]$ – are correspondingly matrices of pliancy, masses and damping

$U, \dot{U}\ and\ \ddot{U}$ – are vectors of acceleration of velocities and travels.

$\ddot{Q}$ - is a vector of seismic impact acceleration.

Solution to the wave equation in which the displacement varies only in the direction of wave propagation and is constant in the directions orthogonal to the propagation direction.

Consider an elastic tower structure whose normal modes are defined by u(x,t) The deflection at any point x can be expressed in terms of the normal modes and generalized coordinates q(t) as :

$$u(x,t) = \sum_{j}^{n} \phi_j\,(x) q_j(t) \qquad ..(14)$$

Let

$$q = \int_{-\infty}^{\infty} q(j\Omega)e^{j\Omega t}d\Omega \qquad .. \ (15)$$

$$q = \int_{-\infty}^{\infty} j\omega q(j\Omega)e^{j\Omega t}d\Omega \qquad ..(16)$$

$$Q = \int_{-\infty}^{\infty} Q(j\Omega)e^{j\Omega t}d\Omega \qquad ..(17)$$

$$Q = \int_{-\infty}^{\infty} j\omega Q(j\Omega)e^{j\Omega t}d\Omega \qquad ..(18)$$

$$Q = \int_{-\infty}^{\infty} -\omega Q(j\Omega)e^{j\Omega t}d\Omega \qquad ..(19)$$

For a sample record $x(t)$ from a stationary random process the frequency composition of $x(t)$ may be conveniently described by the Fourier transform of the autocorrelation function. In terms of transform pairs, the relationships between the power spectral density function $S(f)$ and the autocorrelation function $R(T)$ is written as

$$S(f) = \int_{-\infty}^{\infty} R(\tau)e^{-i2\pi f\tau}\,d\tau \qquad ..(20)$$

$$R(\tau) = \int_{-\infty}^{\infty} S(f)e^{-i2\pi f\tau}\,df \qquad ..(21)$$

In terms of circular frequencies, the transform pairs may be expressed as:

$$S(\Omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} R(\tau)e^{-i\Omega\tau}\,d\tau \qquad .. \ (22)$$

$$R(\tau) = \int_{-\infty}^{\infty} S(\Omega)e^{-i\Omega\tau}\,d\Omega \qquad ..(23)$$

The relation between the autocorrelation function and the spectral density function is given by,

$$R_{qj}(\tau) = \int_{-\infty}^{\infty} S_{qj}(\Omega)e^{-i\Omega\tau}\,d\Omega \qquad ..(24)$$

It is possible to obtain standard deviations of the seismic response for the present generalized seismic damage mode depending on the cumulative time average value to obtain the following models substituting equations (14-24) in equation (13) and rearrangements yields;

$$u_{ijk}(t) = \frac{1}{2\pi}\int_{0}^{\infty}\frac{S_{qj}(\Omega)}{k^2[\left(1-\frac{\beta^2}{\beta_n^2}\right)^2+\left(\frac{2\zeta\beta}{\beta}\right)^2]}d\Omega \qquad ..(25)$$

Thus, the variance of the seismic response with multi-mode shapes is

$$u_{ijk}^2(t) = \sum_{j=1}^{m}\frac{S_P(\beta_i)\beta_j\phi_{ij}^2\,\phi_{id}^2}{9\zeta_j k_j^2} \qquad ..(26)$$

The stress

$$\sigma_{ijk} = \frac{k_{ijk}}{A}u_{ijk}(t) \qquad ..(27)$$

The symbols $_{ij}$, $_{id}$ represents the eigen vectors for modal matrix of the structure, and d is the location where the seismic load is applied, $\beta_i$ is the eigenvalues (structural damping) of the structure which is different for various nuclear towers.

## RESULTS AND DISCUSSION

When a large seismic occurs near a nuclear power station, it is important to confirm safe conditions in a nuclear tower. It takes time and many hands to confirm the conditions for whole tower in nuclear power plant after a seismic. Otherwise, this proposed paper estimates the facilities damage condition accurately and promptly by standardized evaluating scheme based on the database of the nuclear power station, characteristics of the dynamic response and seismic wave propagation. The validity of the proposal mesh model and deformation is shown in Figs.(5,6).

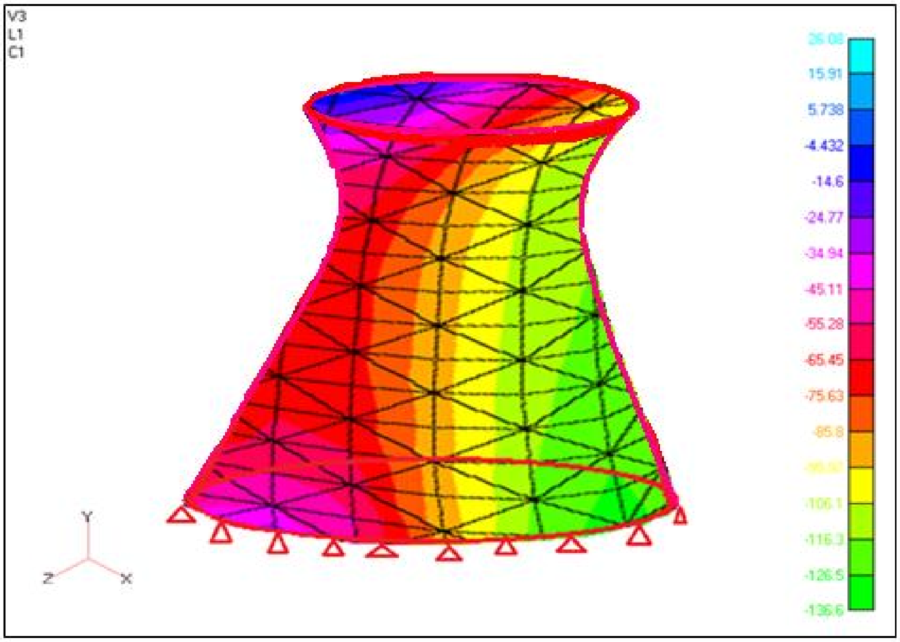

**Figure (5) nuclear tower mesh**

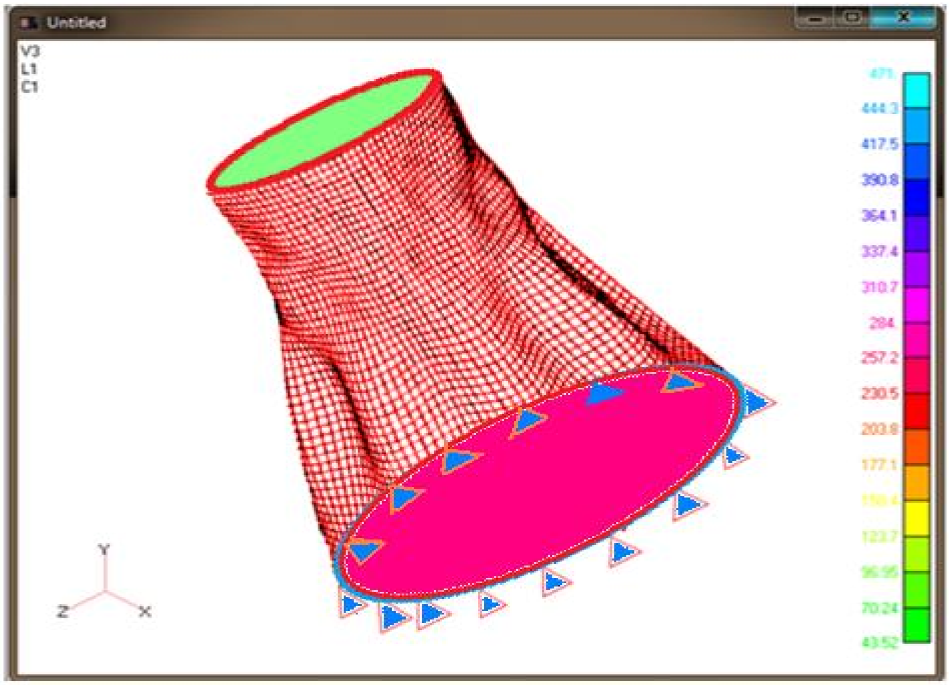

**Figure (6) Nuclear tower deformation**

The effect of tower modal selection on the displacement and stress response predicted using a modal simulation was investigated. For the nuclear tower, it was found that the bending and shell modal basis offered the only accurate prediction of tower shell displacement and the best prediction of max shear stress and bending and tower shell e stress, the bending modes offered the best approach as it produce behavior in the displacement or stress PSDs, did not increase the size of the coupled set of modal equations, and did not have the added complication of identifying tower modes, There is a clear relationship between changes in structural integrity and shifts in the modal parameters of a structure. Additional is still needed to extend the promising results obtained for translation of nuclear tower structures. Since modal shift s can be detected at low excitation levels, it may be possible to use various ambient excitations seismic. Therefore, the simulation model monitoring modal parameters of nuclear power plant structures that are excited by these ambient forces to determine the quality of the data that can be obtained, also a simultaneous investigation into simple excitation techniques that would permit modal analyses to be easily performed. The sensitivity of the modal parameters to changes in the structural integrity is usually determined analytical by examining nuclear tower maximum shear stress Fig.(7) that has been damaged. It is, therefore, recommended that a data collection and modal parameter using FORTRAN power station program to build up a base of historical data from which modal parameter changes can be related to actual failure or damage. Response spectra of the observed seismic motions exceed response spectra for the standard tower motion in the periodic wide band spectrum.

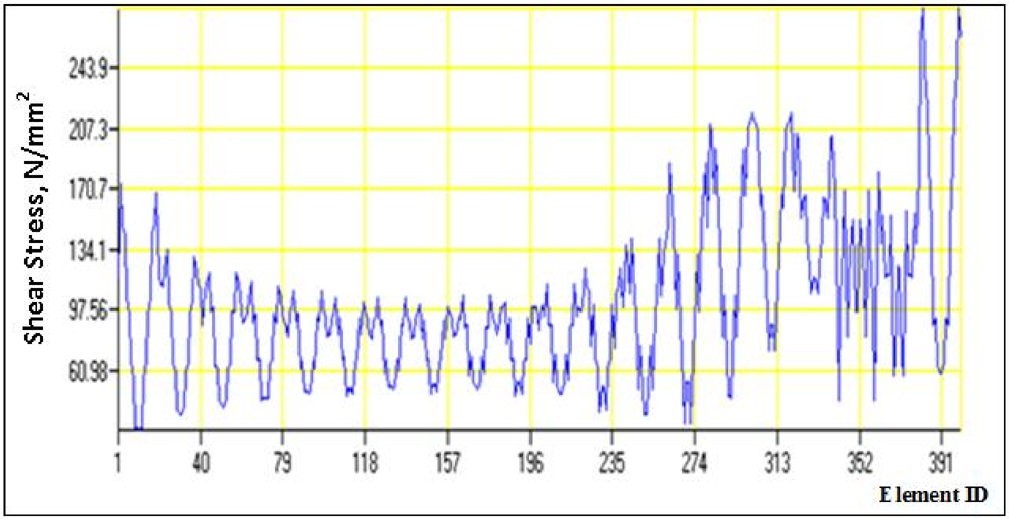

**Figure (7) Nuclear tower structure max shear stress**

Adequate shear due to seismic vibration on the tower caused damage to this structure. Only the rigidity of the tower combined with the support, not penetrated with large doors, is preventing full collapse of the structure.

For structural tower design based on seismic load approach, it is very important to assess ability of a structure to develop and maintain its resistance in the inelastic range.

A measure of this ability is ductility, which may be observed in a material itself, in a structural element, or to a whole structure. To achieve a ductile behavior of the tower, it is necessary that the shear strength of the structure is greater than the tensile strength of reinforcement to ensure a kind of bending failure Fig.(8).

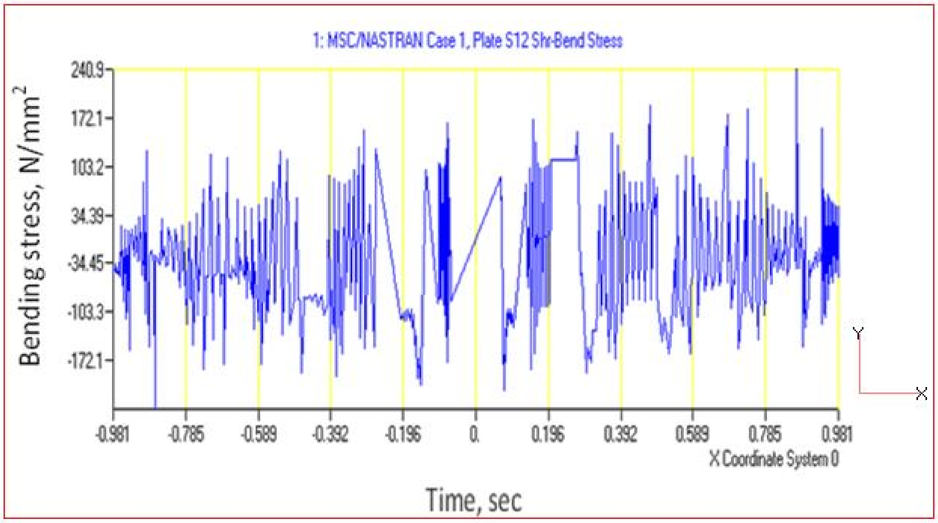

**Figure (8) Nuclear tower structure bending stress**

Analysis model for seismic response of horizontal direction uses a simplified bending transformation and sharing transformation of the nuclear tower, the effects of connection between the effect of the nuclear tower shell and input seismic response is shown in Fig.(9) and other factors of tower translation connection model is evaluated as shown Fig.(10-11).

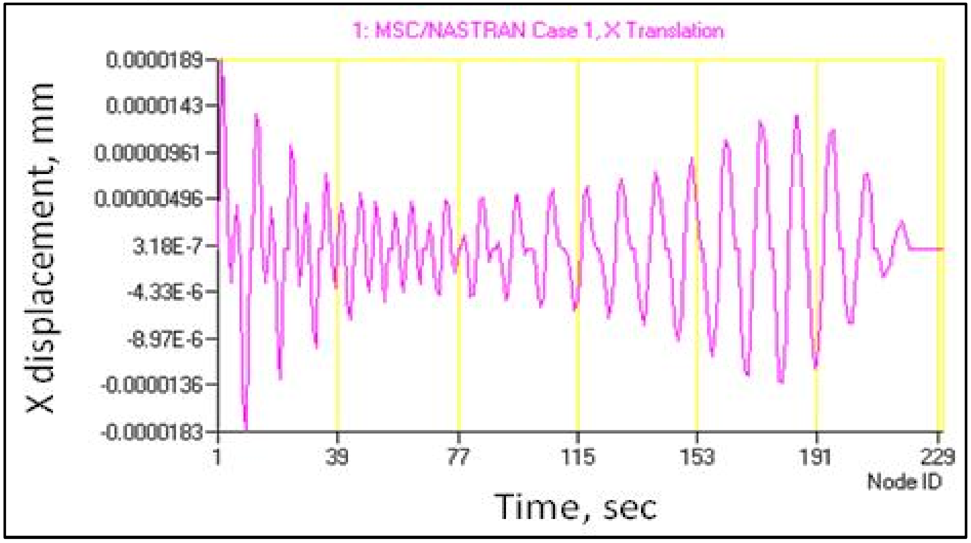

**Figure (9) Nuclear tower structure translation in X- direction**

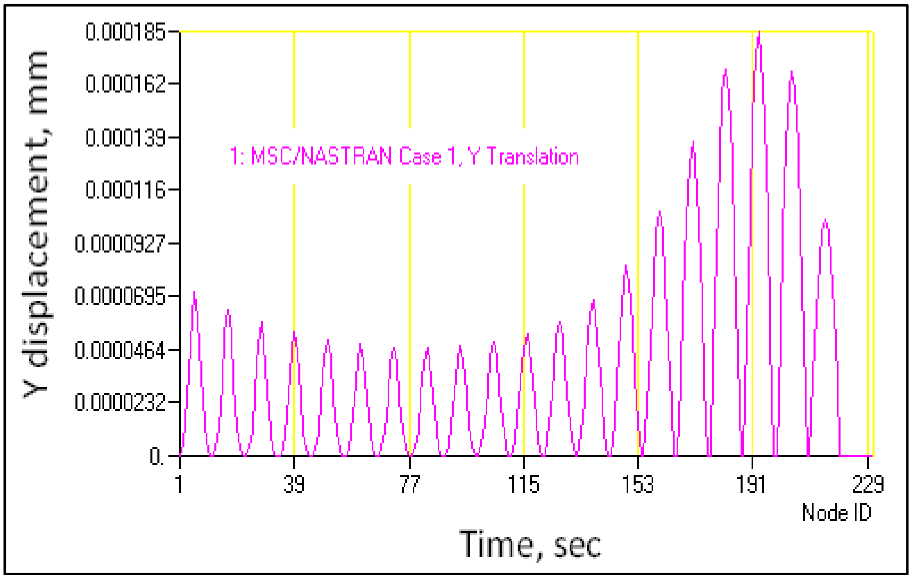

**Figure (10) Nuclear tower structure translation in Y- direction**

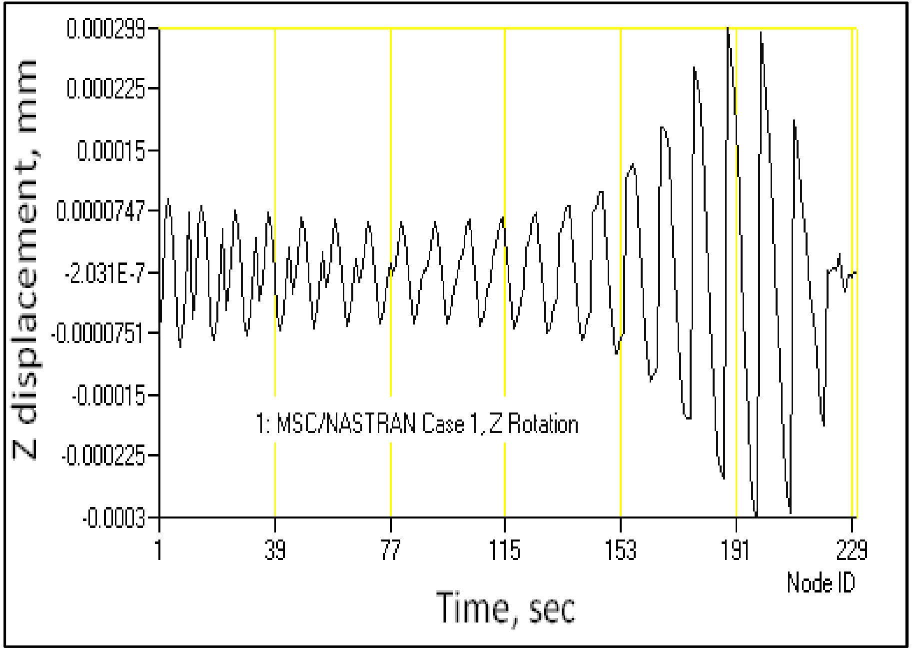

**Figure (11) nuclear tower structure translation in Z-direction**

## CONCLUSIONS

The effect of the variation of seismic motion on the response of the transmission nuclear tower system has been investigated in this paper. The structure of the nuclear tower is modeled by elements and the nonlinear dynamic behaviors of shell are taken into account. The input of seismic motion is taken as displacement time histories. The real data from the close digital arrays of strong motion seismographs are selected. Artificial seismic displacement records are also developed and used in the analysis. The nonlinear time history analytical method is used in the analysis. The influence of the boundary condition, spatially varying seismic excitations, incident angle of the seismic wave and wave travel on the system are considered.

The seismic excitation has a largest effect on the responses of nuclear tower. Assuming that the longitudinal of the tower motion and the direction of the fatigue propagation coincide with the longitudinal direction of the nuclear tower could not obtain the maximum responses of the system. The assumed velocity of propagation of seismic vibration has a significant effect on the response of system to seismic tower motion. In order to obtain a representative analysis of the system, an accurate estimation of the tower velocity is required.

The boundary condition has an obvious effect on the response of the nuclear tower in order to obtain accurate results, and the uncorrelated tower motion gives bigger responses. The case of uniform support excitation does not produce the maximum response in the nuclear tower. The multiple support excitations, which is a more realistic assumption, can result in larger response. The effect of spatially varying tower motions cannot be neglected.

Based on the obtained results, seismic motion and the apparent velocity provide the most critical case for the response calculations. This study demonstrates that the nuclear motion spatial variation effect is very important to transmission to the system.

There are several designs in seismic engineering, making use of experimental results, computer simulations and observations from past earthquakes to offer the required performance for the seismic threat at the site of interest. These range from appropriately sizing the nuclear tower structure to be strong and ductile enough to survive the shaking with an acceptable damage, to equipping it with base isolation or using structural vibration control technologies to minimize any forces and deformations. The method typically applied in most seismic-resistant structures, important facilities, landmarks and cultural heritage buildings use the more advanced techniques of isolation or control to survive strong shaking with minimal damage.

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