NONLINEAR DYNAMIC BEHAVIOUR OF OFFSHORE GUYED TOWER

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CERTIFICATE

This is to certify that the thesis entitled, "**Nonlinear dynamic behaviour of Offshore Guyed Tower**", being submitted by **Risheendra Singh Bisht**, to the Indian Institute of Technology, New Delhi, for the award of the Degree of "**DOCTOR IN PHILOSOPHY**" in Civil Engineering is a record of the bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of our knowledge, has reached the requisite standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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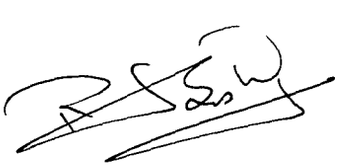

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ABSTRACT

Present study deals with the investigation of the dynamic response of idealised Exxon Guyed Tower under regular and random sea waves in the presence of steady current, wind and earthquake. The responses are obtained both in time and frequency domains for regular waves. Both approaches duly consider the system non-linearities such as nonlinear force -excursion relationship of guylines, nonlinear hydrodynamic drag force and variable added mass.

In the time domain analysis, Newmark's time integration scheme is used to integrate the equation with iteration employed at each time step to tackle the nonlinearities. A two cycle interpolation technique is used to obtain faster convergence to steady state response.

In the iterative frequency domain technique, the equations of motion are written in the frequency domain. The system nonlinearities are handled using the Newton-Raphson method for simultaneous equations. Since the use of exact Newton-Raphson iteration scheme becomes computationally very expensive, the Jacobian in the Newton-Raphson scheme is evaluated approximately without losing the exactness of the results. Further, the solutions are obtained in normal co-ordinates. These make the iterative procedure computationally very efficient. The iterative frequency domain analysis provides same results as those of the time

domain analysis in much less computational time. For random wave loading, which is simulated for a given sea surface elevation spectrum, iterative frequency domain method is used to obtain the response. For both regular and random sea states, a parametric study is conducted to investigate the effects of current velocity, initial guy cable tension, number of higher modes, fixity of the base and hysteretic behaviour of the force - excursion relation of the guy cables on the response. Due to the dynamic motion of the tower, the tension in the cable continuously fluctuates and hence, it is highly prone to fatigue damage. Therefore, the fatigue life estimate of the cable is also investigated using the Palmgren-Miner Cumulative Fatigue law and S-N curve approach for sea states idealized by regular waves.

Response of the Guyed Towers to low frequency second order wave forces in the random ocean environment is determined using a simplified procedure in which hydrodynamic loads are calculated using Morison's equation. The second order drift force is considered to be proportional to the square of the wave elevation and is simulated using a drift force coefficient and the time history of slowly varying wave envelope in random sea. The response due to the second order wave forces is obtained incorporating the nonlinear force-excursion behaviour of the guy lines. The solutions are obtained using the iterative frequency domain technique. Investigations have been carried out to reflect the relative importance of response due to second order wave forces with respect to the response due to first order wave forces. The statistics of the response

due to second order wave force alone and due to the combined first order and second order wave forces are also evaluated.

Responses of the Guyed Tower to the combined actions of wind and wave, and wind, wave and current are obtained using the iterative frequency domain analysis. Both gustiness of wind and wave are considered to be stationary random process and the two are assumed to be uncorrelated. The time histories of water particle kinematics and wind velocities on the exposed portion of the tower are simulated from their respective power spectral density functions. Davenport's wind velocity spectrum and the Pierson Moskowitz (wind driven) sea surface elevation spectrum are used for this purpose. For generating the time histories of wind velocities, it is assumed that the wind velocities are fully correlated along the height of the tower. For the purpose of duly considering the effect of the structural displacement on the hydrodynamic loading and nonlinear guyline resistance, the mean and fluctuating component of the wind forces are added together and applied onto the structure (i.e. responses are not separately obtained for mean and fluctuating components of the wind). The responses of the tower are compared between the cases when (i) wave forces are only acting (ii) wave and wind forces are acting together and, (iii) wave, wind and current forces are acting together. The results highlight the conditions when wind induced vibration assume importance.

Finally, the seismic response of the guyed tower is obtained with and without the presence of wave and current. For the analysis, two

regular waves (10.24 sec/12 m and 5.12 sec/6 m) and N-S component of the El Centro Earthquake are used. The responses are obtained in time domain (using Newmark's integration procedure). Time integration technique is used in order to investigate the effect of initial condition of the tower on the seismic response. Initial condition refers to the steady state oscillation of the tower when the earthquake first hits the tower. The nature and magnitude of the seismic response with and without wave forces acting on the tower are investigated with the help of numerical study.

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