DYNAMIC RESPONSE OF ARTICULATED OFFSHORE TOWERS

by

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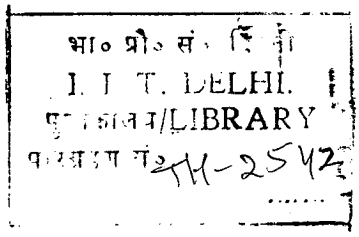
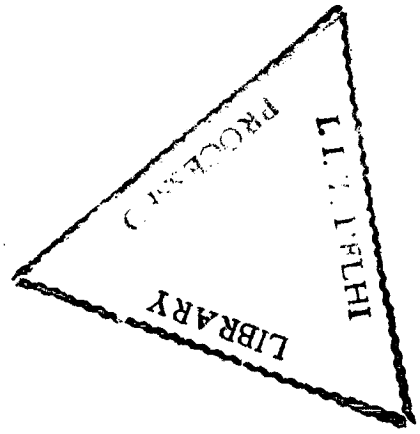
Dedicated to a great sufi saint of India
Hazrat Khawaja Qutubuddin Bakhtiyar "Kaki"
(Rahmatullah Alaih)
whose spriltiuaal guidance always showed me light in the dark passages of my personal and academic life.





CERTIFICATE

This is to certify that the thesis entitled "**Dynamic Response of Articulated Offshore Towers**", being submitted by Mr. Nazrul Islam to the Indian Institute of Technology, New Delhi, for the award of the Degree of 'Doctor of Philosophy' in Applied Mechanics, is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which is to the best of my 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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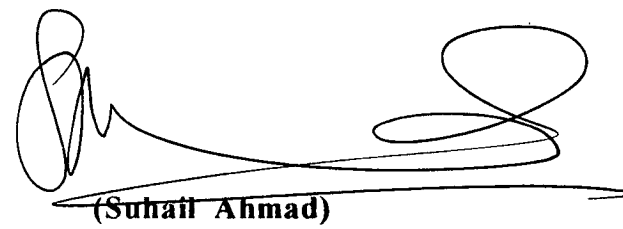

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ABSTRACT

An articulated tower is one of the compliant off-shore structures, used as a mooring, production and service facility. It essentially consists, of a buoyant shaft, connected to the sea-bed through a universal joint. The compliance of the tower avoids the concentration of high overturning moment and the resulting stresses. Under deeper waters the bending moment distribution may further be reduced by the introduction of one or more intermediate hinges resulting in a configuration called, multi-hinged articulated tower. The present study investigates the dynamic behaviours of a single and double-hinged articulated towers (SHAT/DHAT), considering the non-linearities due to variation of submergence, buoyancy and added mass, instantaneous tower orientation, under regular, long crested and short crested random sea. The seismic loads, ocean current, wind and wind-driven-waves are judiciously incorporated in the analysis. Articulated tower is idealized as an inverted buoyant pendulum. The nonlinear equation of motion in terms of rotational degrees of freedom (θ_1, θ_2), has been derived by Lagrangian approach. Like the structural model all the above mentioned time varying random loads are appropriately modelled considering all the non-linearities involved. An iterative time domain integration scheme has been employed. Computer software ART'97 for the dynamic analysis has been developed consisting of various subroutines to simulate and compute complex environmental loads. The programme has been fully validated at various stages. Response study starts with an input of regular sea waves. This computationally economical approach is well suited for a preliminary study. A more realistic analysis involves the simulation of ocean environment as long crested random sea. Instantaneous mass, stiffness, damping and force vectors are generated to yield a converged response parameter. Short crested random sea represents the marine environment more appropriately. Though it involves an expensive simulation technique but emerges with

several interesting results. An off-shore articulated tower analysis is incomplete without considering the wind loads, active on it's super-structure. Present study simulates the wind speed fluctuations by means of Emil Simiu's sea site wind spectrum for compliant structures. A correlated random sea loading has been considered to be active on the sub structure simultaneously. Significance of seismic analysis has been widely realized in recent years. El-Centaro earthquake ground acceleration record has been employed in the present study to obtain a horizontal component of seismic loads. Earthquake strikes the structures in the presence of active sea waves. In a detailed dynamic analysis hydrodynamic, wind, and seismic loads and their realistic combinations are handled in systematic fashions in order to highlight the worst effect on the behaviour of SHAT and DHAT. Time histories of salient response parameters are developed, and statistically analyzed. Power spectra present the nonlinear behaviour in an appropriate fashion. Sub and super harmonic responses and other salient characteristics of results are identified. Detailed investigations are carried out to study the behaviour of DHAT in deep water conditions vis-a-vis SHAT for the satisfactory service and survival.

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