

SEISMIC RESPONSE ANALYSIS OF OFFSHORE STRUCTURE SUPPORTED BY GROUP PILE FOUNDATION BY CONSIDERING WAVE AND CURRENT ACTION

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Abstract – This the structural design and analysis requirement of the offshore structure supported by the group pile foundation and subjected by the seismic, wave and current which induced the forces and moment in the fixed type offshore structure. The seismic response analysis of the fixed type offshore structure supported by the group pile foundation and subjected by wave and current load, the offshore platform is discretized using the Structure Analysis Computer Software (SAP2000) which is based on the finite element method, the wave force on the pile can be calculated by using the linear Morison equation. The hydrodynamic loading on horizontal and vertical tubular members and also the dynamic response of the fixed type offshore structure together with the distribution of the displacement, axial force and bending moment at the pile of the offshore structure at the regular and extreme condition due to load. The height of the wave is increase or decrease which depends upon the velocity of the wind. The result of the study show that the effect of the offshore structure when it is only subjected with the seismic force and effect of the offshore platform by the seismic force along with the wave and current force and also study the condition of the liquefaction where the offshore structure is placed.

Key Words: Seismic response, offshore platform, Wave, Current load, SAP2000 and pile foundation.

1. INTRODUCTION

Offshore structure is defined as structure which is mainly installed in the marine environment usually for production and transmission of oil, gas, electricity etc. we are studying the seismic response of offshore structure supported by group pile foundation by considering the wave simultaneously. The analysis of offshore structure is a most demanding set of tasks faced by Structural Engineering. Over and above the usual condition and situations met by land-based structure, offshore structure have the added complication of being placed in an ocean environment where hydrodynamic interaction effect and dynamics response become major considerations in their design. The foundation support condition and character of the dynamic response of not only the structure itself but also of the riser system for oil extraction adopted by them. Invariably, non-linearity's in the description of the hydrodynamic loading characteristics of the structure- fluid interaction and in the association structural response can assume importance and need be address.

The offshore structure may be analyzed by using the static or dynamic analysis method. The static analysis method is sufficient for the structure, which is rigid enough to neglect the dynamic force associated with the motion under the time dependence environmental loading. On the other hand, structure which are flexible due to their particular form and which are to be used in the deep sea must be checked for dynamic loads. Dynamics analysis is particularly important for the wave of moderate height is they make the greatest contribution of the fatigue damage and reliability of the offshore structure. The dynamic response evaluation due to wave force has significant roles on the reliable design of the offshore structure.

In the design and analysis of the fixed offshore structure many nonlinear physical quantities and mechanisms exist that is difficult to quantify and interpret in the relation of the hydrodynamics loadings. The calculation of the wave loads on the vertical tubular member is always of the major concern to the engineers, especially recently when such study are motivated by the need to build solid offshore structure in the connection with the oil and natural gas production. The effect of the various wave patterns on the offshore structure have been investigated by numerous researchers.

1.1 .Wind Load

The wind forces are exerted upon the portion of the structure that is above the water as well as on any equipment, deck house and derricks that are located on the platform. The wind speed may be classified as:-

1. Gusts wind speed that average less than one minute in the duration and its return periods is about 100years.
2. Sustained wind speeds that average one minute or longer in duration.

The wind data should be adjusted to the standard elevation, such as 10m above the means sea level, with a specific averaging time, such as one (1) hour.

The spectrum of the wind speed fluctuations about the average should be specific in some instances. For example compliant structure such as Guyed Tower and Tension Leg platform in the deep water may have natural sway periods in the range of one (1) minute, in which there is significant energy in the wind speed fluctuations.

The following should be considered in the determining appropriate design wind speed, which is given below:-

For Normal Conditions:-

- a) Frequency of occurrence of the specified sustained wind speed from various directions for each month or season.
- b) The persistence of the sustained wind speed above specified threshold for each month or season.
- c) The probable speed of the gust associated with sustained wind speeds.

For extreme conditions:-

The projected extreme wind speed of specified direction and averaging times as a function of their recurrence interval should be developed. Data should be given concerning the following:-

- a) The site measurement, data of the occurrence, magnitude of the measured gusts and sustained wind speed, and wind direction for the recorded wind data during the development of the projected extreme winds.
- b) The projected number if the occasion during the specified life of the structure when sustained wind speed from specific direction should exceed a specific lower bound winds speed.

1.2 Wave Force

The wind driven waves area a major source of the environmental force on the offshore structure. Such waves are irregular in shape, vary in height and length and may approach a platform from one or more direction simultaneously. For these reason the intensity and distribution of the force applied by wave are difficult to determine. Because of the complex nature of the technical factor that must be considered in developing wave dependent criteria for design of the platform, experienced specialist knowledge in the field of the meteorology, oceanography and hydrodynamics should be consulted.

In that area where prior knowledge of oceanographic condition is insufficient the development of the wave dependent design parameter should include at least the following steps:-

- i. Development of all necessary meteorological data.
- ii. Projection of the surface wind field.
- iii. Prediction of deep water general sea-states along storm track using the analytical model.
- iv. Definition of maximum possible sea state consistent with geographical limitations.
- v. Delineation of the bathymetric effect on the deep water sea state.
- vi. Introduction of probabilistic technique to predict sea state occurrence at the platform site against various time base.
- vii. Development of design wave parameter through physical and economic risk evaluation.

1.3 Active Geologic Processes

It describes the ground motion and effect on the offshore structure, it has mainly three steps to describe about it:-

1.3.1. General:-

In the many offshore areas, geologic processes associated with movement of the near surface sediment occur within time periods that are relevant to fixed platform design. The nature, magnitude and return intervals of the potential seafloor movement should be evaluated by site investigation and judicious analytical modeling to provide input for determination of the resulting effect on the structure and foundations.

1.3.2. Earthquake:-

The seismic force should be considered in the platform design for area that are determined to be seismically active on the basis of the previous records of the earthquake activity, both in the frequency of occurrence and in magnitude. Seismic activity of an area for purposed of the designing of the offshore structure is rated in terms of possible severity of the damage of these structures. Seismicity of an area may also be determined on the basis of the detailed investigation.

Seismic consideration should include investigation of the subsurface soil at platform site for instability due to liquefaction, submarine slides triggered by the seismic activity, proximity of the site to faults, the characteristic of the ground motion expected during the life of the platform, and the acceptable seismic risk for the type of the operation intended. The platform in shallow water that may be subjected to Tsunamis should be investigated for the effect of the resulting forces.

1.3.3 Faults:-

In some offshore areas, fault planes may extend to the seafloor with the potential for either vertical or horizontal movement. Fault movement can occur as a result of seismic activity, removal of the fluid from the deep reservoir or long term creep related to large scale sedimentation or erosion facilities is close proximity to fault plane intersecting the seafloor should be avoided if possible.

2. LITERATURE SURVEY

Bor-Feng Peng¹, Ben Chang², Bee-lay Leow³ and Sam Nandlal⁴ [1] study Nonlinear Dynamic Soil-Pile Structure-Interaction Analysis of the Offshore Platform for the Ductility Level Earthquake under Soil Liquefaction condition and they gave the following conclusion:-

- ❖ The thickness of the pile is higher as compared to the pile which is used for structure construction. Higher thickness of the pile increases the ductility and reduces the liquefaction condition.
- ❖ The depth of the pile penetration is deeper to resist the horizontal load which acting at the offshore structure.
- ❖ The maximum displacement occurs at the top-head of the pile due to horizontal load.
- ❖ The maximum bending moment occurs at the top head of the pile because of acting the wave force at the pile.
- ❖ The fixed type of the offshore structure is more suitable as compared to the other type of offshore structure.

Takeshi Maki¹ and Hiroshi Mutsuyoshi²[2] study the Response Behavior Of RC Pile under Severe Earthquake and they gave the following conclusion:-

- ❖ When the pile install in deeper depth in the soil then it increase the restoring force of the pile and pile little affected by the earth pressure.
- ❖ The formation of the plastic hinge is very low when pile is installed properly at the deeper depth.
- ❖ Under the reversed cyclic loading condition, passive earth pressure becomes high with the increase of the displacement amplitude. This is caused by the compaction of the soil particles around the pile body, and restoring force of the compaction soil ground may provide the remarkable progress of the damage pile.
- ❖ In the dynamic condition, strain rate of the pile is more as compared to the strain rate in the static condition.

Bai Degui¹, Chen Guo Xing² and Wang Zhi Hua³[3] study the Seismic Response Analysis of the Large Bridge Pier Supported by the Group Pile Foundation Considering the Effect of the Wave and Current Action and they use the Morison formula with the Stoke's fifth order wave theory for the calculating the wave and current force at the pier of the bridge and they give the following conclusion:-

- ❖ The little affects on the accelerations response on the piles when the piles are only subjected to the waves and currents of the ocean.
- ❖ The wave and ocean current has great effect on the relative displacement of the pile body. The wave and ocean current make the relative displacement against the water-current direction decreasing, and make the one along the water current direction increasing and influence extent increase with flow velocity increasing, but the change the law with wave height is closely related to the earthquake ground motion characteristic.
- ❖ The moment on the pile body is increasing when the height of the wave increasing.
- ❖ In the case of the seismic force along with wave and current force, the displacement at top-head of pile and moment on the pile is high as compared to only pile subjected by wave and current force.

Jing-Jong Jang¹ and Guo Jyh-Shinn²[4] study the is Analysis of Maximum Wind Force for Offshore Structure Design, the result of this paper is calculating the drag force due to wind load on the offshore structure by considering the linear and nonlinear approach, and conclusion of this paper is given below:-

- ❖ The probability density function of the turbulent drag force including the nonlinear approach substantially deviates from the normal distribution in that probability density is greater for the larger force.
- ❖ In the nonlinear approach higher yield probability density for the large drag force than linear approach. In evaluating the variance of the turbulent wind induced drag force from wind spectrum. . The spectral density function of the squared wind speed is very large in the comparison with spectrum of the wind speed; however the contribution of the former to the variance of the drag force is extremely small. Extreme wind induced drag force are evaluated through both the linear and nonlinear approach on an offshore structure having a projected area of 2,000 m² for the wind speed of 44.7m/sec at the 30m above the surface of the water.

Toyoaki Nogami[5] study the paper is Effect of Offshore Environment on Dynamics Response of Pile Foundation and conclusion of this paper is given below:-

The pore fluid in the soil mass affect the dynamic response of the soil deposited by not by simply increasing the stiffness of the soil but also coupling the soil skeleton motion with pore fluid motion. All those are affected by loading rate relative to the pore fluid diffusion rate, boundary condition and stress gradients. The coupling effect is more predominant for higher permeability of the soil. When the soil permeability is low, a mode wave transmitted primarily to the fluid is distinctly different from those primarily transmitted to soil skeleton and decays very quickly with distance. Under the static and drained condition, the submersed soil response is identical to dry the soil response. Under the dynamic condition; however the transient pore fluid redistribution depends upon the rate of loading and permeability of the soil. The response of the submersed soil is closer to the undrained condition when the combinations of those are less favorable for the pore fluid movement. The larger pore fluid motion relative o the skeleton soil is higher damping generated. When the soil submersed below the water-table, the water above the soil deposit ca affect the dynamic response analysis of

submersed soil under the water. It is well known that the Winkler model based on the cylindrical plane strain condition can produce the dynamic p_i response reasonable well for p_i in the single phase soil medium.

Shehata E. Abdel Raheem¹, Elsayed M.A. Abdel Aal², Aly G.A. Abdel Shafy³ and Fayez K. Abdel Seed⁴[6] studies the Nonlinear Analysis of Offshore Structure Under Wave Loadings and they gave the following conclusion:- The offshore structural analysis is used to obtain the platform displacement response under varying external loading. The deflection of the platform is studied for individual and combined wind and wave force. Jacket type offshore structure is displacement, axial force, bending moment, natural mode and frequencies of the free vibration are evaluated. A comparison of maximum displacement at all nodal point for various current incidence angles is introduced. The result indicates a significant effect of the current incidence direction.

3. CONCLUSIONS

From the above studied we found many conclusion which is given below:-

- ❖ Axial force, bending moment and the displacement of the pile is directly proportional to the increasing the wave height or by increasing the velocity of the wind.
- ❖ During the designing and analysis of the offshore structure only primary wave will take for the calculation because primary wave is only one seismic wave which can be travel in the solid and fluid.
- ❖ When the water table is low where the pile is installed and type of the soil at the seabed is sand, when the Primary wave release then it increases the velocity of the wave and current load. Primary wave is just like as shaking force which help to increase the pore pressure of the soil by filling the water in the void of the soil and it reduce the effective stress of the soil which make condition of the liquefaction.
- ❖ In the case of the seismic force, the height of the wave is increase and also increase maximum deflection at the top-head of the pile as compared to in absence of the seismic force.

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