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Effect of Type of Support on The Responce of Offshore Sructure Under Seismic Load

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Abstract

The seismic force has very important effects in the response of offshore structures and it is considered as applied dynamic forces. The seismic must be taken in consideration in designing stage due to their high effects on the safety of platform under earthquake. In this paper a comparison in response between offshore structures with fixed support at sea bed and with embedded piling support. AL-Basrah oil port (ABOP) is taken in consideration as a case study where two models are used, in the first model the pile –soil interaction (PSI) is neglected and the fixed support is used in the level of sea bed however in the second model, the effect of pile –soil interaction is considered. For two models the finite element analysis was performed in linear behavior for piles and deck while the soil is treated as nonlinear. The results are shown that the natural frequency for fixed support is more than for structure with piling support and the responses are more influenced by the near in frequency between structure and seismic action .

Keyword: offshore, seismic, pile, soil plastic model.

1-Introduction

Fixed offshore platforms are designed to support the decks such as using gravity concrete base or piles . The platform during its lifetime is subject to different environmental loading like waves, winds and earthquake API [1]. M.Fatimi [2] studied the seismic load effects on the offshore with and without take consideration pile –soil interaction using two dimensional finite element model for jacket structure. Ali mohammad [3] considered the behavior of the batter pile group under seismic loads where 3D Finite Element Method is developed to find the dynamic response where the constitutive model for analysis is a Hardening Drucker-Prager model . In this paper the effect of different type of supports on the response of offshore structures under dynamic load of a seismic excitation is studied.

2 – Platform Description

AL-BASRAH OIL PORT (ABOP) in the south of iraq is taken as a case study where the platform (A) in this port represents the mooring structure. This platform consists of fourteen piles for supporting the deck . The Water depth is 30 m and the superstructure is supported by piles without steel jacket where the piles are extended from lower part of deck to the supporting soil without any jacket or diagonal members. The batter steel piles are used with inclination (1:4) . The upper level of deck is above the Mean Sea Level(MSL) by 9 m and the pile length reaches to 34.5 m at the sea bed and to 81.5 m to the tip of it. The diameter for all pile is 1.20 m and different sections are used in construction the deck which have dimension 9.15m *12.19m . The pile is analyzed with fixed support and for the real situation which deals with embedded piles in the soil figure(1).

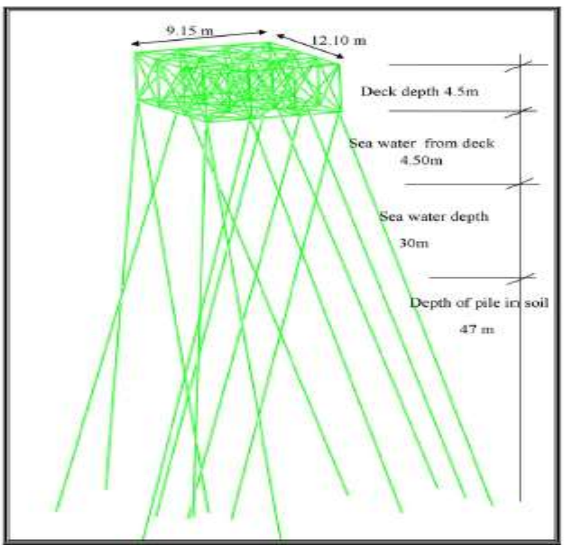

Figure (1) Fixed platform at sea bed level

3 FINITE ELEMENT ANALYSIS

Three dimensional finite element model for the AL-BASRAH OIL PORT (ABOP) is developed . ABAQUS program is used to perform simulation for the platform and the soil in linear or non linear behavior . In this work , the elements of soil , pile and other members are chosen according the physical behavior in one , two and three dimensions .

3.1 Elements OF Problem

From ABAQUS program library , the elements are selected for each members according to its physical behavior under loads. Three dimensional brick element of soil is used (C3D20RP) , 20 nodes ,with linear pore pressure, and quadratic displacement[4] . For piles and members of deck, B32 element is selected for the simulation where each elements has three nodes to give more accurate results with quadratic polynomial equation and six degrees of freedom where three in translations and three in rotations, see figure (2,3).

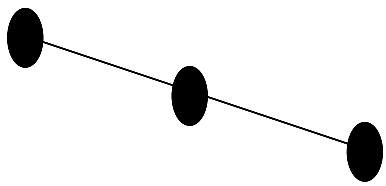

Figure (2) Quadratic frame element for pile.

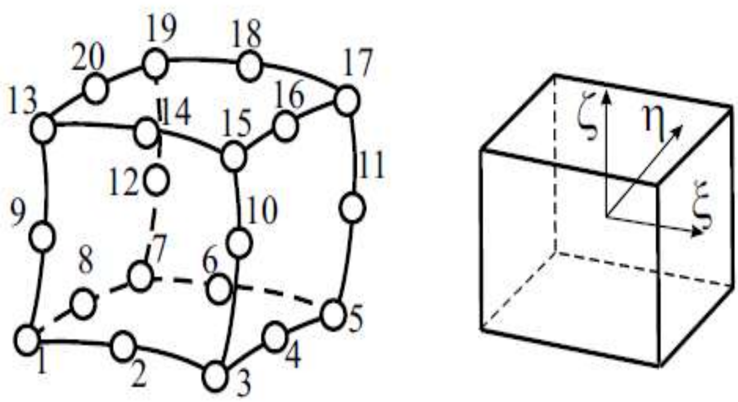

Figure (3) Brick element for soil.

4 SOIL CONSTITUTIVE MODEL

The relationship between the stress and strain is restricted by constitutive model of elastic or plastic where laboratory tests are performed to define the parameters for each models . However, in recent years the finite element analysis is used to represent the constitutive models of soil and to find its response in the same time , the soil behavior according to constitutive model is compared with site results.

4.1 PLASTIC MODEL

The plastic material when subjected to load the elastic and plastic strain are sustained and there isn't recover to its original state . According to the elasticity theory the Hook' low is the best to find the elastic strain while the plasticity theory is needed to estimate the plastic strain. The plasticity theory is developed to predict the materials behavior under loads if it is exceeding the elastic limit[5] . In this theory, there are parameters to describe material and to give mathematical model to estimate the material in elastic or plastic strain .There are many plastic models for soil and in this paper the cam clay model is used.

4.1.1CAM Clay Model

Cam clay model is depended on plasticity theory to predict the change in volume under different loading cases [6]. According to the critical state theory , the cam clay model is developed to predict the strength of soil under pressure and the volume changes by the shearing. The critical state theory deals with three important parameters , effective mean stress (p'), deviatoric stress (shear stress) q and specific volume (v). Depending on the effective principle stresses the effective mean stress and shear stress are calculated as

$$p' = \frac{1}{3}(\sigma'_1 + \sigma'_2 + \sigma'_3) \qquad (1)$$

$$q = \frac{1}{\sqrt{2}}\sqrt{(\sigma'_1 - \sigma'_2)^2 + (\sigma'_2 - \sigma'_3)^2 + (\sigma'_3 - \sigma'_1)^2} \qquad (2)$$

and the specific volume is defined as $\upsilon = 1+e$. In (p' - q) plane as shown in figure (4), the yield surface for Cam clay is un ellipse and governed by

$$\frac{q^2}{p'^2} + M^2\left(1 - \frac{p'c}{p'}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

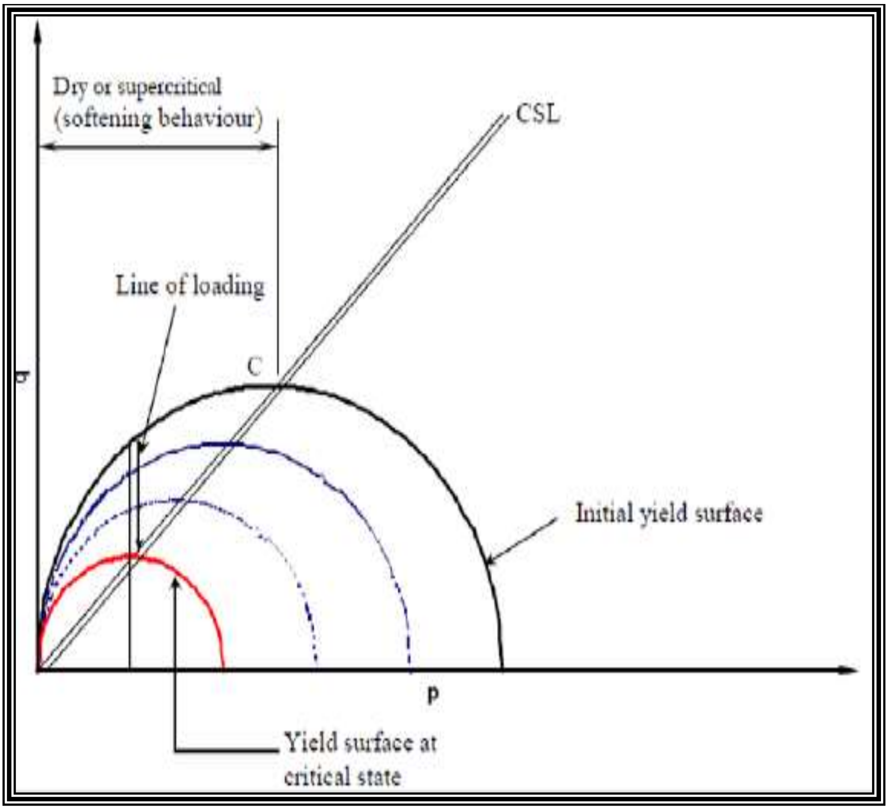

Figure (4) Cam clay yield surface(5).

5 SOIL EXPREMENTAL TESTS

5-1 Triaxial Test

This method is used to find the shear strength for different types of soils and to find the relationship of stress –strain for different values of confined pressures . The soil sample in this test is subjected to pressures in all around and then applying vertically loads on sample until reaches failure .

Radial and axial strains are recorded to find the elastic properties for soil like Poisson's ratio , ν and Young's Modulus(E) and shear strength of soil (cohesive and internal soil friction). Figure (5) Shows the results of tests for three samples.

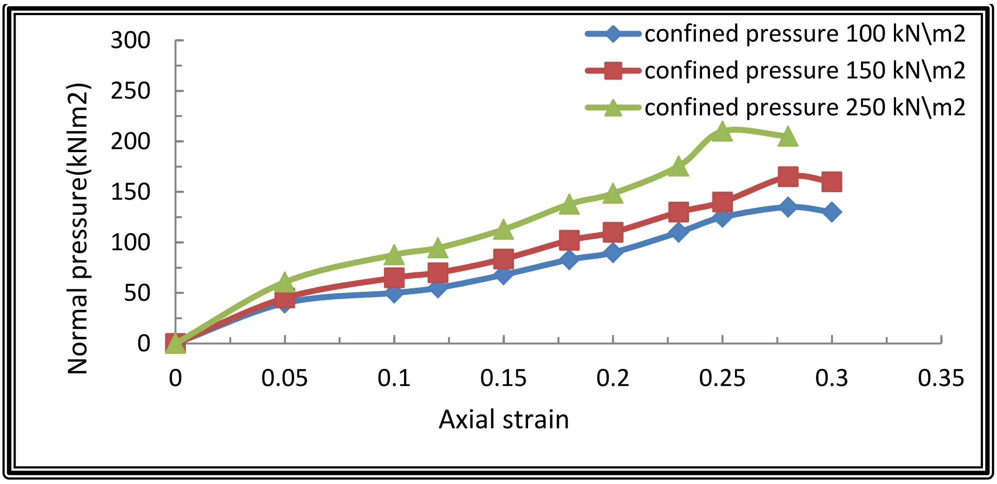

Figure (5) Triaxial compression test.

5-2 Consolidation Test

The consolidation tests are performed to calculate the quantity and rate of volume reduction in a horizontally confined clay sample which is subjected to applied different vertical pressure. The consolidation curve is plotted between the applied load and measured voids ratio. The obtained data is very important in calculating the preconsolidation pressure, coefficient of secondary compression, coefficient of consolidation, compression index and swelling index of the soil , see figure (6).

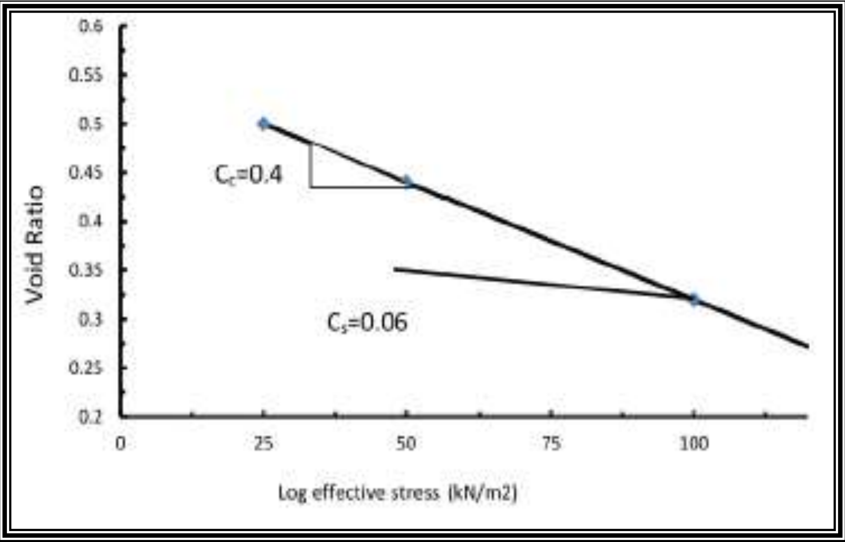

Figure (6) Consolidation test

5-3 Soil –Steel Shear Test

The interface shear box test is very important in the Geotechnical Engineering using a classical direct shear equipment. A square plate represent shear box (100 mm * 100 mm) move laterally at middle-depth was used in contact with steel plate. Vertical stress is applied by adding dead loads on a hook, horizontal displacements are observed. The correct interface shear stress values are obtained by subtracted the shear stress value consistent to the frictional between the lower and the upper parts of box from the measured interface shear stress. The main purpose this test was to estimate the mechanical properties of interface between clay soil and steel plate figure (7) .

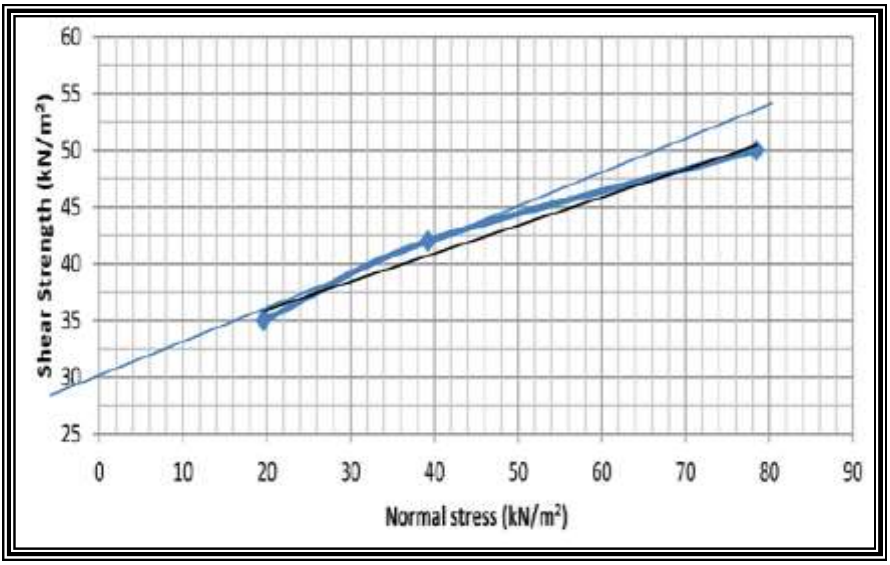

Figure (7) Shear - Steel test.

6- Cam Clay Parameter

The Cam clay model is used to represent a soil in the plastic model . Parameters are taken from the tests and the yield criteria for surface failure in the cam clay model is an important step . The past field condition is needed to define the initial yield surface. The calculated three mean stresses are signed on the figure (8) and the critical state line intersects the yield failure surface through the maximum deviatoric stress . Figures (9) shows the deviatoric relation with volumetric strain and mean effective stress under loading. All parameters to represent soil are shown in table (1).

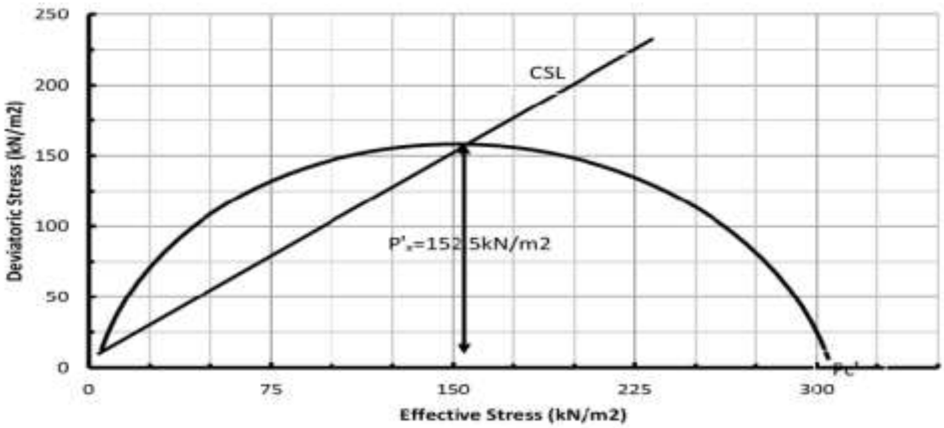

Figure (8) Critical State Line .

Model Parameters			
1	General	Elasticity	Plasticity
2	$\rho (kg/m^3)=2170$	$K=0.026$	$\lambda=0.174$
3	$e_0=0.44$	$\upsilon=0.3$	Stress ratio $M=1$
4	$\gamma_w\ (kN/m^2)=9.81$		Initial yield surface =152.5kN/m2
5	Shear stress (kN/m^2)		Wet yield & flow stress rate =1

Table (1) Cam Clay Parameter .

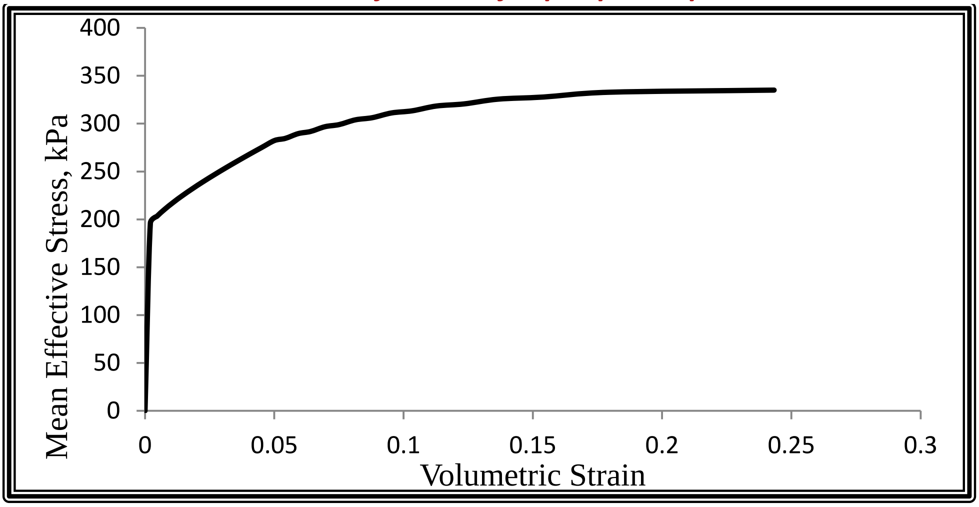

Figure (9) Strain –mean effective stress.

7 –Seismic Representation

The behavior of AL-Basrah oil port (ABOP) platform A1 is studied to find its expected responses when subjected to seismic load in future . The EL-Centro earthquake is used to simulate the seismic load and (acceleration –time) for EL-Centro earthquake is performed in ABAQUS program to do port analysis[7]. The port is simulated in two case with and without soil support where its assumed as fixed in the sea level and finding the response in the deck and support through the displacement and shear force in addition to bending moment at the pile head . The structure is analyzed taking into consideration the soil effect on the response of deck and pile where the deck displacement , shear and the moment in pile are measured at sea level. The E-W component for EL-Centro Earthquake is used in this analysis figure (10).

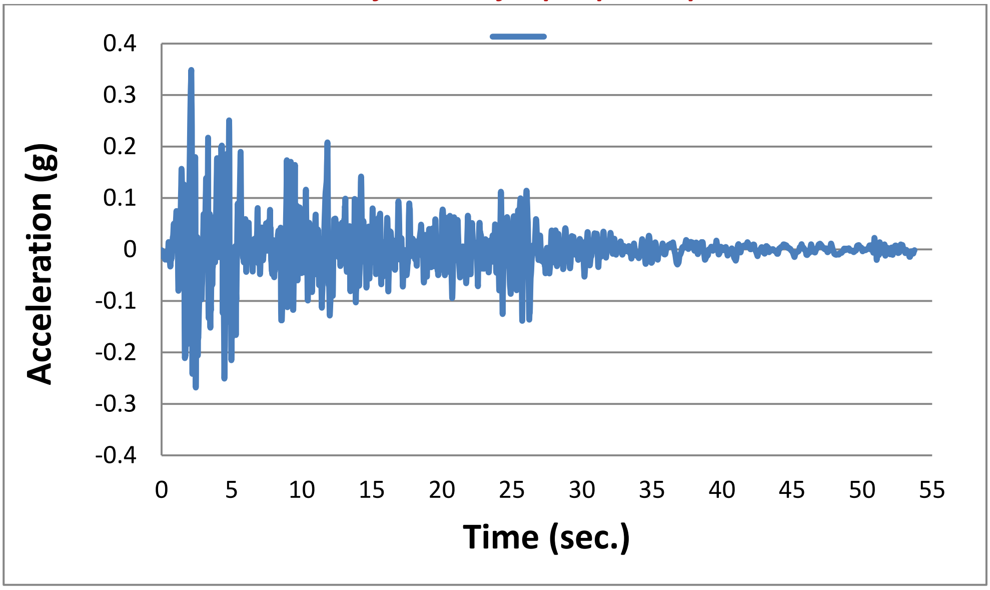

Figure (10) EL-Centro Earthquake Data.

8- Results and Discussion

EL Centro earthquake is used to simulate the seismic activity in the region of the port. AL-Basrah oil port figure (11) is used as a case study to find the response under seismic load . The results show that the natural frequencies and mode shapes are found by eigenvalue analysis . The natural frequencies of structure are shown in table (2) for the fixed support which is used in first model and for the model of piling support . The deck displacement of fixed support is less than for deck which is supported by embedded piles in elastoplastic soil as shown in figures (12,15). The shear force and bending moment at the pile head in the second model are greater than for the fixed support in the first model. The differences in results due to the natural frequency of seismic load is near to the natural frequency of the structure with embedded piling support .

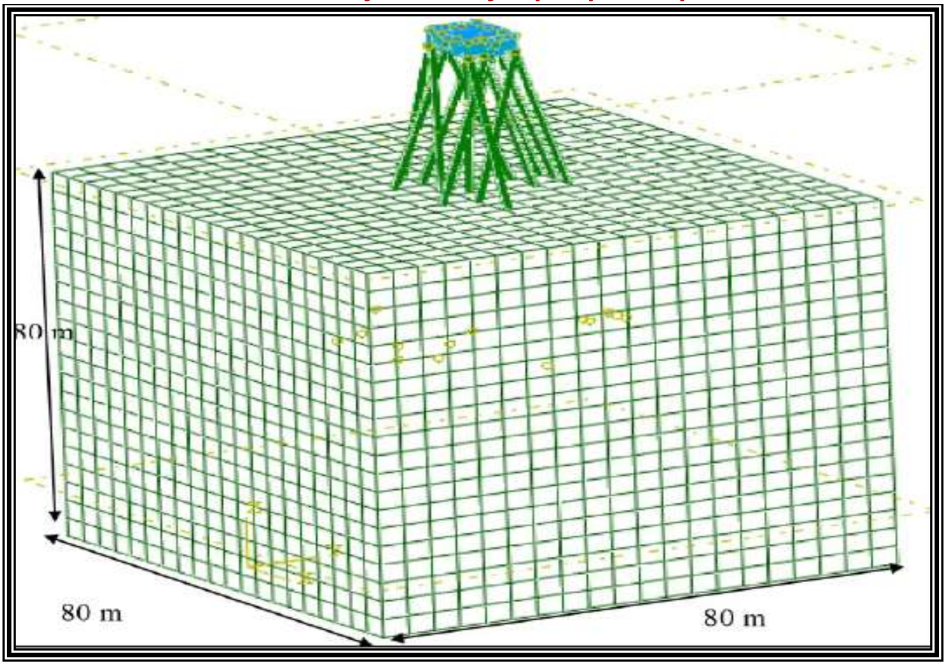

Figure (11) AL-Basrah oil port Model.

Mode Number	Fixed support(Hz)	Piling support(Hz)
1	2.488	2.320
3	3.705	3.002
3	3.826	3.151
4	4.076	3.368
5	4.223	3.488
6	4.246	3.676

Table (2) Natural frequencies for fixed and piling support.

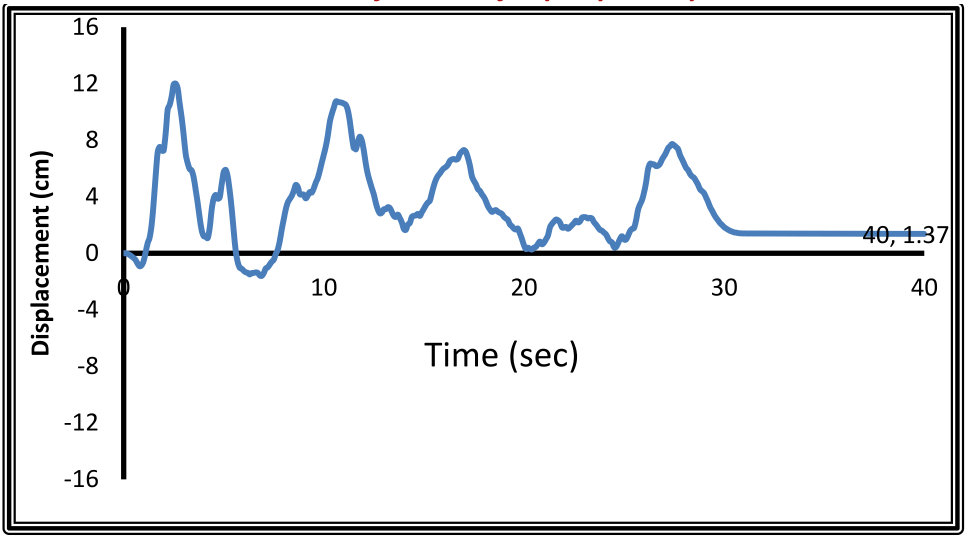

Figure (12) Deck- displacement in fixed Support model .

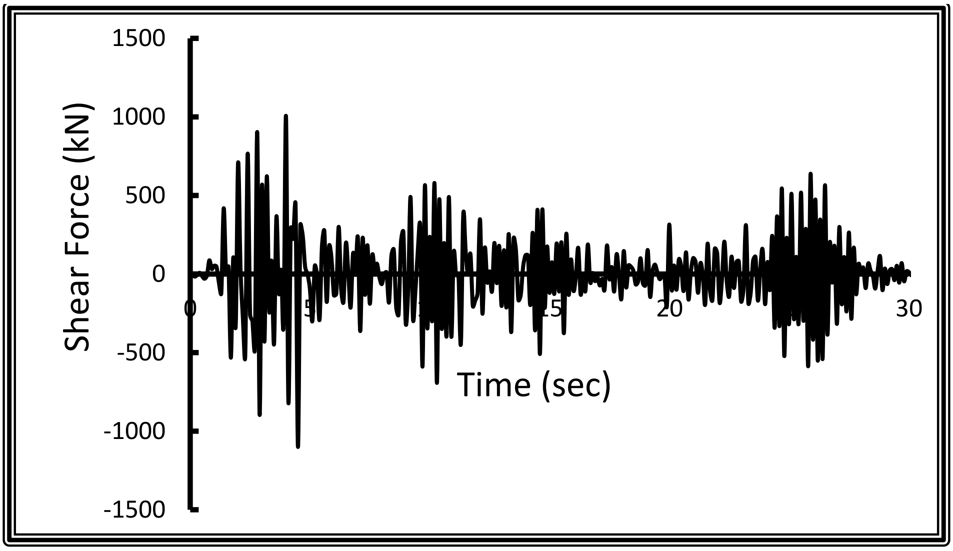

Figure (13) Shear force – time for pile head in fixed Support model.

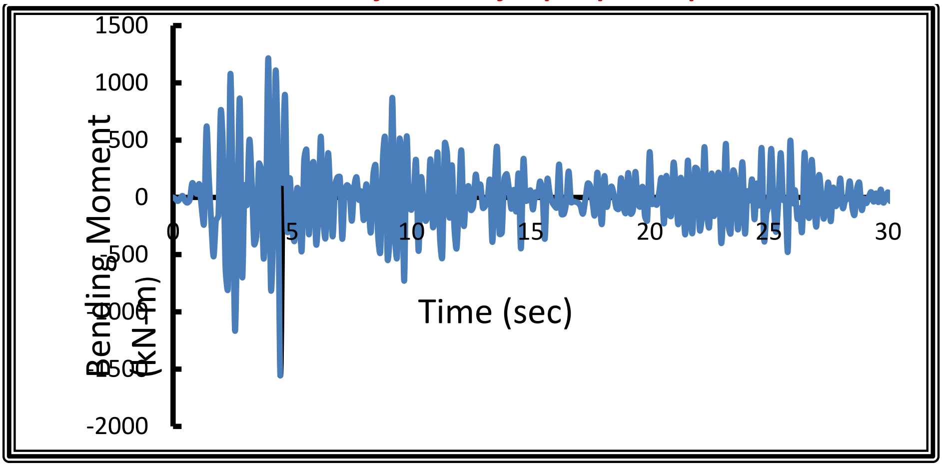

Figure (14) Bending moment – time for pile head in fixed Support model .

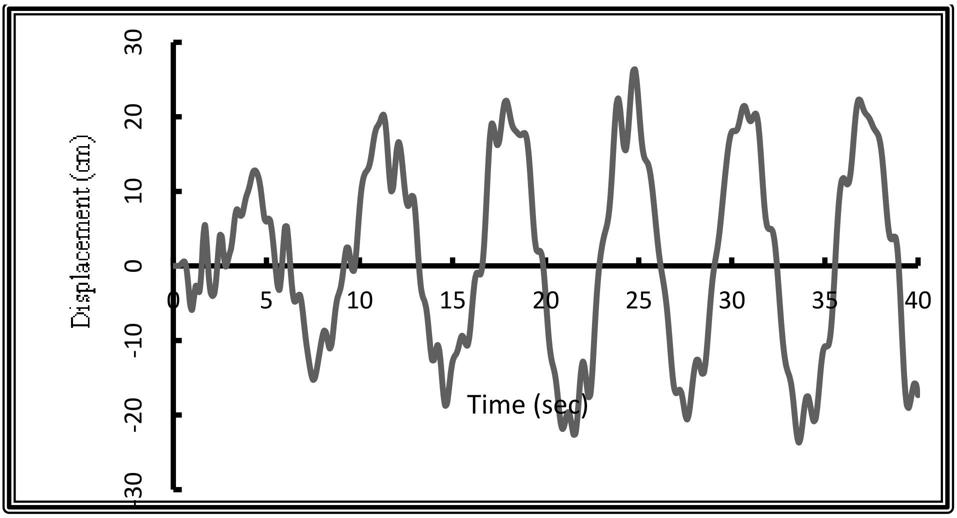

Figure (15) Displacement – time for deck in piling support model.

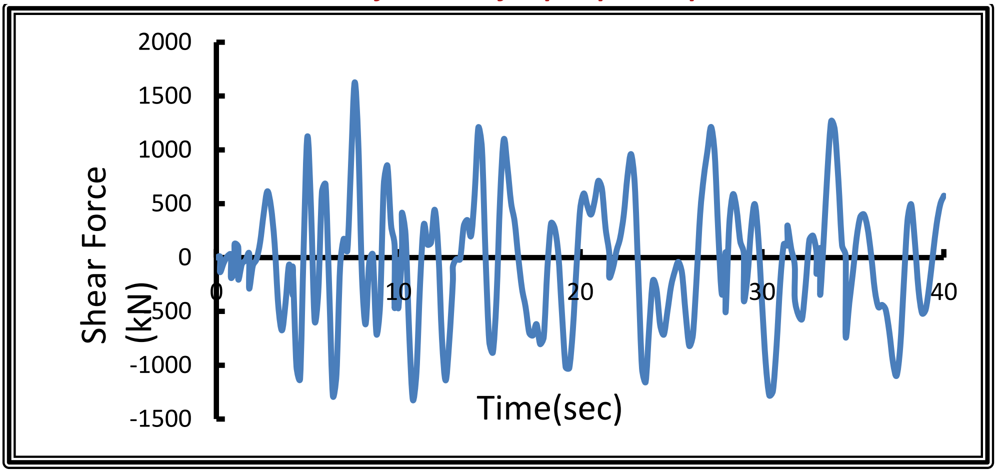

Figure (16) Shear force – time for pile head in piling support model.

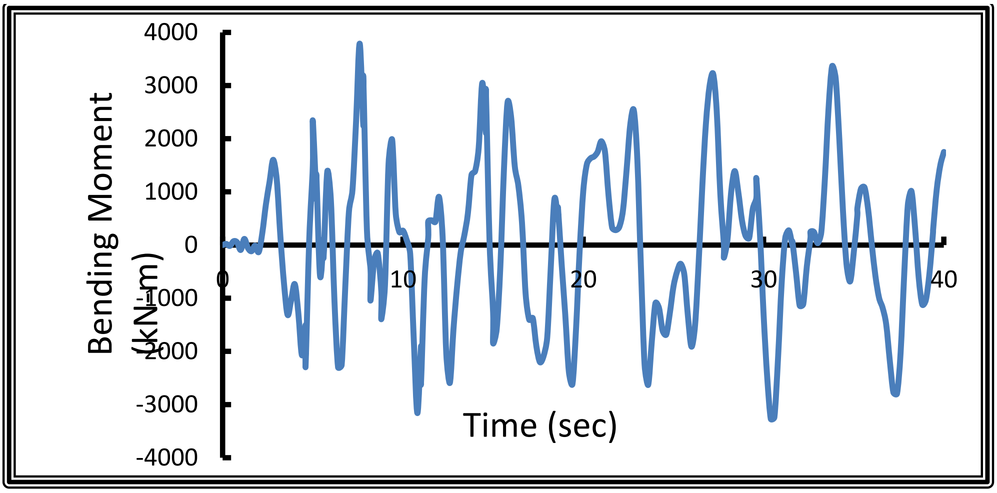

Figure (17)) Bending moment – time for pile head in piling support model.

9- Conclusion

The main conclusions are :

1- Natural frequencies for structure with fixed support is more than for structure with piling support.
2- The responses of structure in shear and bending moment with fixed support are less than responses for it with piling support.
3- Responses of structure are more influenced when the frequencies for the earthquake and structure are closed .

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