Behavior of marine pile under dynamic earthquake loading

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Abstract

Earthquake is one of the most destructive phenomena in nature. Iran country is located on the high risk zone of world earthquake chain resulting to serious dilemma in every few years. The number of serious earthquakes in coastal area of our country in last few years has been considerable (e.g. Occurrence of earthquake in Bandarabbas, Gheshm Iland, etc. in 2005 and 2006). Inclined pile performance against lateral loading is much better than vertical ones. However their design and construction are difficult. Therefore the vertical marine piles are more common structural elements to handle and conduct different environmental loadings through deep sea bed level where the soil provides enough strength as a safe foundation. In this study the nonlinear behavior of vertical marine piles under earthquakes has been investigated,structure and soil has been modeled using Plaxis Software. The soil characteristics such as φ and c was obtained by in-situ field study in coastal area of Bandarabbas. Running model for a critical condition of lateral and vertical Dynamic loading for a set of sample marine piles time history of pile displacement was obtained. The decreasing rate of shear stress coefficient respect to bed depth was graphically presented. The results showed promising for optimum and reliable pile design of harbors and offshore structures not only in the vicinity of the study area, but also for a wide range of the coastal zone of southern part of Iran.

1-Introduction

Iran country has a long marine boarders in north and south. This intension is associated with a variety soil parameters and different layers. Numerical modeling is important tools to estimate the vertical and lateral settlement of marine piles in the costal zone.

In this paper plaxis ver.7.29 software was employed to simulation the soil-pile interaction due to earth quake loading.

2-theoretical back ground

soil-pile interaction analysis can be performed in following ways:

a)Method based on maximum lateral soil pressure

b)Method of bed reaction(vinkler method)

c)Method of continuous medium

d)Finite element method

2-a)In first method the ultimate values can be obtained. Hansen(1961)employed this method to obtain the maximum moument as:[2]

(1)

$$\sum M = \sum_{z=o}^{z=x} P_z \frac{L}{n}(e+z)B - \sum_{z=x}^{z=l} P_z \frac{L}{n}(c+z)B$$

(2)

$$H_u(e+x) = \sum_{o}^{x} P_z \frac{L}{n} B(x-z) + \sum_{x}^{x+L} P_z \frac{L}{n} + B(z-x)$$

Figures 1-a to 1-c shows the soil reaction , shear diagram and moment diagram for atypical soil-pile interaction.

2-b)The method of bed reaction known also as vinkler method is a suitable method for soil simulation.
This method of is able to consider the nonlinearities of soil and radiation damping. According to vinkler(1876)soil is model by a series of separate elastic spring. For a continuous beam on elastic bed the governing equation can be expressed as:[2]

$$\frac{d}{dz^2}(E_p I_p \frac{d^2y}{dz^2}) + \frac{d}{dz}(N_{(2)}\frac{dy}{dz}) - P_{(z-y)} = 0 \tag{3}$$

2-c)In continuous medium method green function which is the base of all boundary integral and boundary element methods is used to determine the displacement due to external loading. The equilibrium of vertical forces acting on the elementary pile segment of fig4 iswritten as:[3]

$$\frac{\partial p}{\partial z} + m\frac{\partial^2 U_p}{\partial t^2} + (k + iwc)(U_p \_ U_{ff}) = 0 \tag{4}$$

2-d)Finite element method is a powerful tool for analyzing soil-pile interaction . In this method volume of soil is divided in to separate elements.

3-Simulation of nonlinear dynamics of soil behavior

Simulation of nonlinear dynamics of soil behavior based on the governing equation and osillatory nature of earthquake,mass,damping and stiffness of the pile have major effect on its behavior Nogami&and Knagai(1988) proposal relations for stiffness, damping and mass of the pile as follows(see Fig2) [5]

$$(k_1, k_2, k_3) = G\xi_k(v)(3.518, 3.518, 5.529) \tag{5}$$

$$(C_1, C_2, C_3) = G\xi_k(v)(113.0973, 25.133, 9.362) \tag{6}$$

$$m_s = \xi_m(v)\rho_s \pi r_1^2 \tag{7}$$

In which $\boldsymbol{G}$ is shear modulus of soil and ξ_k and ξ_m are parameters related to poisson ratio.Wang proposal another model for this problem.his model with springs in parallel or series can be seen in Fig.3.
This figure shows that :the part series near field element(strain harding plastic)and far field element(visco elastic radiation damping) model parallel nonlinear p-y spring &radiation damping-dshpet . Melinakis and Geztas(2002) proposal a different model for this problem. Their model for vertical component of earth quake wave loading is shown in Fig4.

4-Simulation of nonlinear dynamics of soil behavior

on of the difficulties in simuhation of pile and soil is separation of pile and soil due to force transmitin in this study ***R***interface= 0.6 element was used.It was assumed that the soil behavior in small deformation domain is elastic, perfect plastic . Therefore for soil yielding the modified colmb criteria was used triangular,15 node element and behavior of concrete material assumed to be linear elastic[4].

Geotechnical field studies of Bandar abbas area performed using boreholes in different locations with different depths.The results revealed that the parameters of dominant soil layers of the study area are as follows:[1]

first layer(depth=3m):

$\nu = 0.3\ C = 0\ \phi = 29(\deg)\ E = 12000(kN/m^2)\ \gamma_w = 18.5(kN/m^3)\ \gamma_d = 15(kN/m^3)$ second layer(depth=3): $\nu = .3\ C = 0\ \phi = 30(\deg)\ E = 12500(kN/m^2)\ \gamma_w = 17.7(kN/m^3)\ \gamma_d = 15.2(kN/m^3)$

thirdlayer(depth=3m):

$\nu = .3\ C = 0\ \phi = 31(\deg)\ E = 13000(kN/m^2)\ \gamma_w = 17.1(kN/m^3)\ \gamma_d = 15.8(kN/m^3)$

fourthlayer(3m): $\nu = .35\ C = 1(KN/m^2)\ \phi = 24(\deg)\ E = 15000(kN/m^2)\ \gamma_w = 16.8(kN/m^3)$

$\gamma_d = 15.5(kN/m^3)$

A typical pile with a diameter of D=1m , alangth of L = 20 and 30 m , $\gamma = 24kN/m^3$ and $E = 2.1\times10^6\ kN/m^2$, $\nu = 0.2$ was used in a water depth of 5m in this study.

Adead load of 100 KN applied at top of the pile. For earthquake exiting force the Colorado accelerograph with **a** max =0.35g which is similar to that of study area was using this accelerograph as input to the model the pile response can be obtained as output.Fig.5

5-results and conclusions:

Fig.6.compares the lateral displacement of the top of the piles with lengths of 20m and 30m due to earth quake. It is clear from this figure that there is a time leg between earth quake accelerograph and pile displacement. It can also be see that the amplitude of shorter pile displacement is grater than that of the lounger one.

Fig.7.compares the vertical displacement of the top of the pile for piles with 20mand 30 lengths. it is evident from this figure that the amplitude and overal displacement of shorter pile is langer than longer pile in the light of different runs of the model (fig.5)the following conclusions can be drawn:

1-Fig6-7.comparison of lateral and vertical displacement of top two piles with different lengths shows that a decrease of 33% in pile length resulted to an increase in lateral displacement of 19% and vertical displacement of 16%.this could be due to a decrease in total surface friction of shorter pile.

2-Fig.7considering the variation of vertical displacement of the pile with pile length it can be concluded that most of the earthquake loading is tolerated by resisting shear force due to pile skin friction.

References:

[1]: H. G. poulos," *marine geotechnics*",1988

[2]: k.habibagahi, j.ahansen langer," *horizontal subgrade of granular soils in laterally loaded deep foundations*" ,ASTM.pub code:04-1984,pp21-34

[3]: Mylonakis and gazetas.(2002). "*Kinematic pile response to vertical p-wave seismic excitation*" 10.1061/(ASCE)1090-0241(2002)128:10(860)

[4]:Manual of plaxis7.29
[5]: nogami,t.and konagi,k.(1988)."*time domain flexural response of dynamically loaded single pile*"; j.Eng.mechanics.ASCE,114(9).1512-1525]

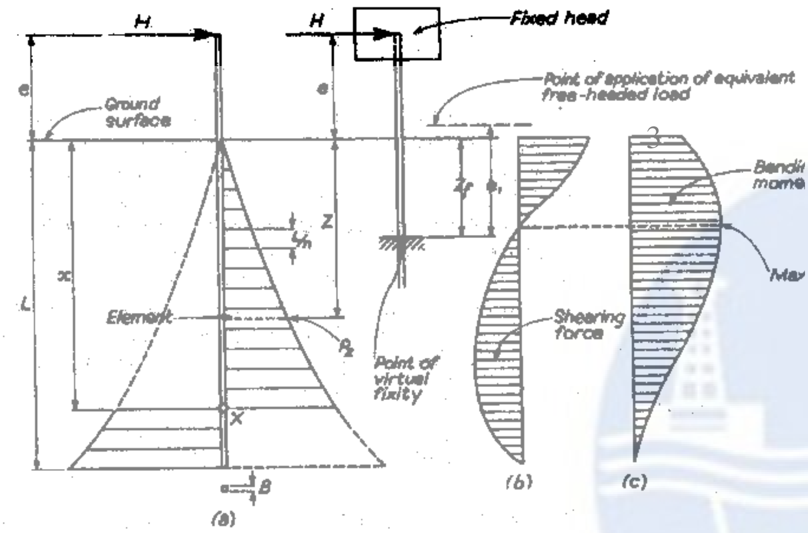


Figure1:Theory honsen(1961)

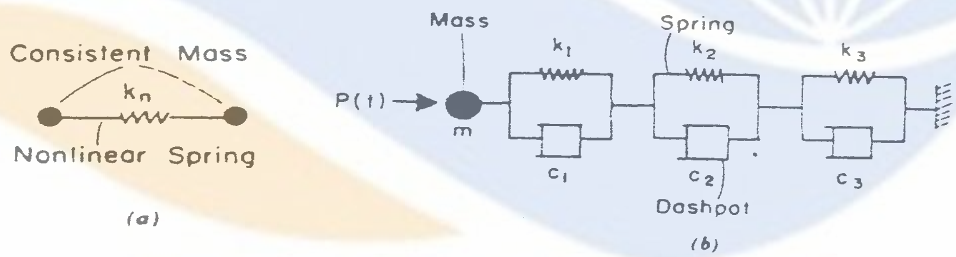
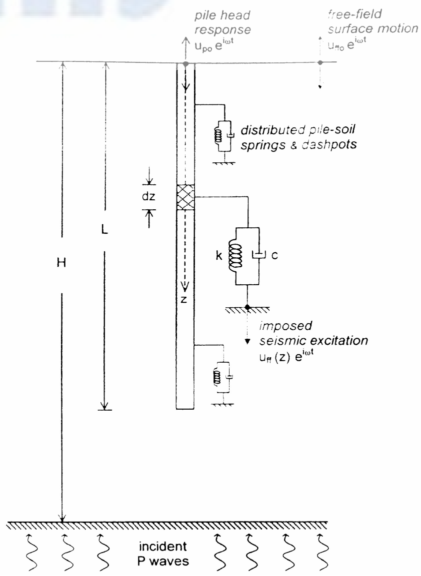
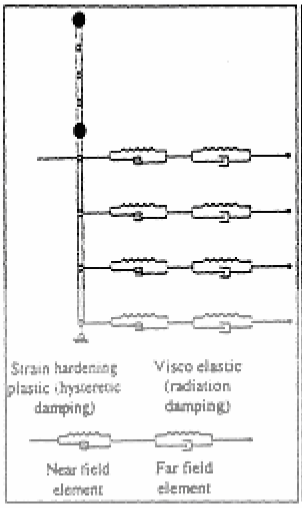
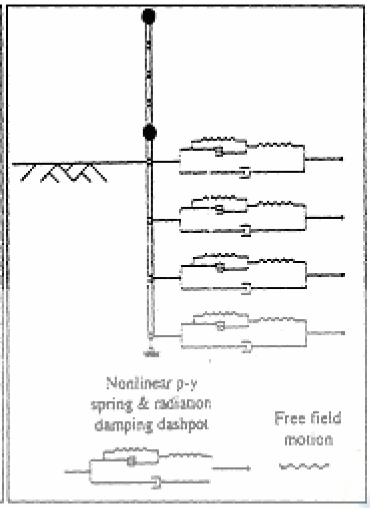


Figure2:model nogami&konagi(1998)







b) Seri form a) Parallel form

Figure3:model wang(1998) Figure4:model mylnakis(2002)

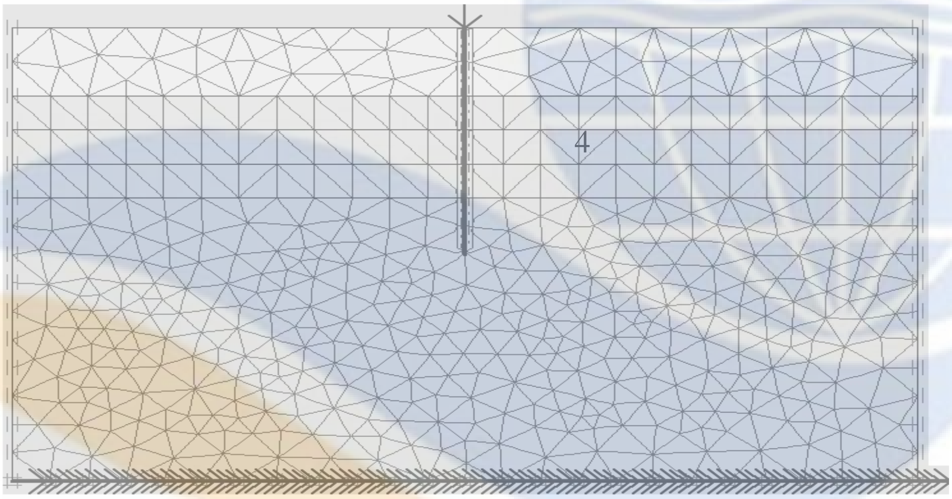


Fig 5:Mesh generation and loading model

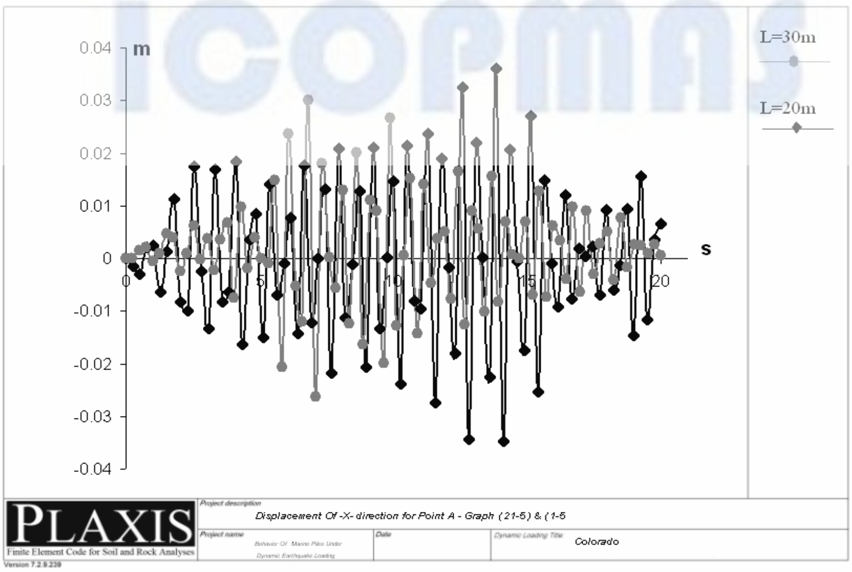


Fig 6:Displacement lateral for pile (L=30m,20m)

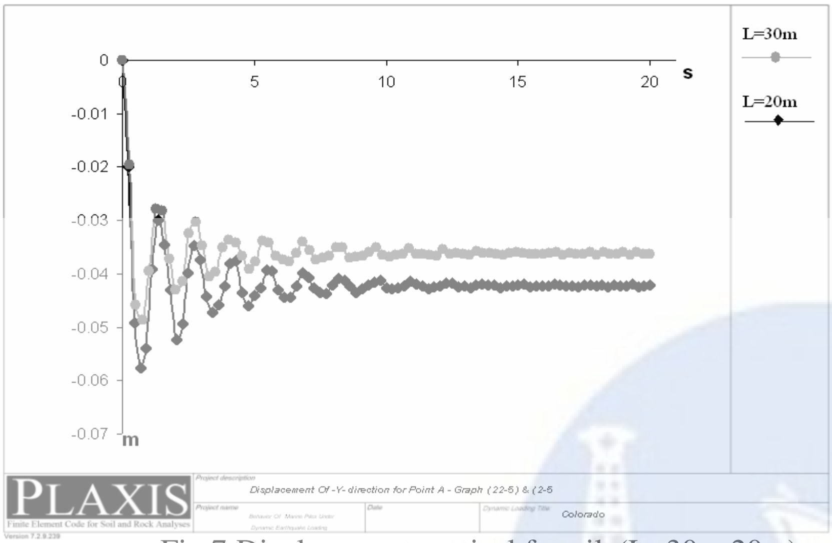


Fig 7:Displacement vertical for pile(L=30m,20m)