SEISMIC PERFORMANCE OF THE PIER CONSIDERING STRUCTURAL - FLUID INTERACTION WITH ANSYS SOFTWARE

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ABSTRACT:

In the present study, as the calculation of forces on the cylindrical structures of the sea has a special complexity, Morrison's mathematical model was used in the software. In addition, the kinematics of water particles is estimated to calculate their acceleration from the fifth-order non-static wave theory (Fenton method). In this paper, the analysis of the pier performance considering structural-fluid interaction using ANSYS soft is presented. Five models with the same period were considered and different wave heights and two different earthquake records of Tabas and Northwich were studied. Finally, node displacement, acceleration and reciprocal interaction forces were extracted and compared with the numerical values. The results indicated that the values of the studied parameters and the type of nodes were similar in the models without a record of earthquakes, but with the estimation of the earthquake, these values would be significant.

1. INTRODUCTION

In recent decades, the coastal construction industry has enjoyed a high rate of growth, and the implementation of constant structures has become more common. The piers have been developed for various applications, including the harbor of ships with sufficient jet, safe harness for hulling ships, providing facilities for transportation of cargo and passengers, creating facilities for carrying out maintenance and other specialized activities. Detailed study of the dynamical behavior of the piers is very complicated due to lack of information about the system components and constituent. During major marine storms that hit the coast, these structures are often exposed to severe damage and overall destruction. The growing expanding of the exploration of vast oil and gas resources and strategic issues has led to the development of the construction of piers and other marine structures on the southern shores of Iran. In the design of various structures, there are constraints such as resistance to loads as well as projection economics that can affect many of the design criteria available. Since the most important factor in fatigue, destruction and decrease in the life of structures is the amount of displacement of the bases due to the forces caused by waves and earthquakes, in this research, we will present and study the displacement diagrams and time curves of tubular shapes.

In 1950, Morrison et al. presented an equation for estimating the forces of the waves on low diameter vertical bases, which became the basis for studies (Ghatarband and Behdarvandi, 2016). This equation is based on empirical coefficients, estimating which has been the subject of research by many researchers, including Kolligan, Carpenter, and Sarp Caia.

One of the investigations carried out in the field of structure-fluid under the influence of earthquake dynamic waves is well-known research by Hardard Guard and Sharan. Moreover, Samerfield method, the Unlimited Element Method, the Sharan boundary condition, and some other analyses provided all attempt to estimate the appropriate conditions in modeling the range of the year or the effects of discontinuing the fluid domain. Yang, Sai et al. provided an analysis of the interaction between reservoir and reservoir fluid. Considering the adequacy of the method of boundary element in the loading of sea, waves and fluid domain modeling have received much attention. Mizotani has also studied the effects of sea waves on the structure of the substrate using the boundary element method. Golshani has also studied the interaction of axial wave symmetrical structures or using transient boundaries in the time domain.
Golafshani et al. [8] reviewed the existing regulations on marine structures and pre-construction standards for the performance levels of offshore platforms after the earthquake. Naghipour et al. have examined different models for

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estimating kinematic particle size of water by Fenton method to estimate the hydrodynamic coefficients and estimate the force of the waves entering the structure by the Morrison equation. In this study, the hydrodynamic forces estimated by the Morrison equation with the measured values show that although the Morrison equation is the most practical solution available for the estimation of wave forces on cylindrical members, the errors in the conservative direction are also noteworthy.

In this research, Shafieifar et al. studied structural interaction and wave interaction and the effect of motion of the structure and its response and two well-known methods (absolute velocity) and (relative velocity) were compared for the analysis of offshore platforms. Structural models are different in terms of stiffness and natural variation, loading states are different in terms of height and time of wave rotation, and hydrodynamic coefficients of force (drag and inertia) are different. The kinematics of fluid particles in all loading states are calculated according to the fifth order Stokes (Fenton) theory. In addition, Morrison formula has been used to calculate the results. The results of this study show that due to the loading frequency (due to the fifth-order stokes theory), natural rotation time and structural stiffness and force coefficients (drag and inertia) have a significant effect on the structure response. It is no not necessarily in a way that the time constant of the design wave constantly reduces with the time off of the natural period of the structure.

Malek and Keinia have studied the dynamic behavior of wharves under the influence of waves and vice versa by formulating equations governing the interactive dynamic effects between water and small diameter members and providing numerical methods suitable for solving these equations. They used an analytical model of the fluctuations of the pier against the waves and their reaction to the earthquake, which shows that the maximum response of the piers occurs under the influence of waves when the frequency of the wave is equal to the structure frequency (Rashidinasab and Behdarvandi, 2017).

The basic issue that distinguishes the dynamic study of the pier from the conventional structures is the presence of water around the bases. Water only causes the hydrodynamic forces of the waves to come from the bases, but also the vibration of the quay under the influence of other forces, such as the forces resulting from the earthquake Morrison equation is used to determine the hydrodynamic forces induced by waves on the basis. This equation can be used for cases where the ratio of the base diameter to the wave does not exceed 0.1, generally written as follows:

$$f = 1/2\rho C_{\downarrow}\, D\, D\, |$$

$$f = \frac{1}{2}\rho C_D D \left| U'_W - \dot{U} \right| \left(U'_W - \dot{U} \right) + \rho C_M \frac{\pi D^2}{4} \dddot{U}_W - \rho \left(C_M - 1 \right) \frac{\pi D^4}{4} \dddot{U}$$

where:

f is horizontal force input on base unit
p is the special mass of water
D is the base diameter
C_M = coefficient of inertia
C_D = Drag coefficient

$\dot{U}_W . \bar{U}_W$ = horizontal acceleration and velocity of water particles at the calculation location of the forces

$\dot{U} . \bar{U}$ = base horizontal acceleration and velocity of at the calculation location of the forces

In solving these equations, two fundamental problems arise: firstly, the input-based force at each moment is a function of relative velocity before the solution of the unknown equations, so the above problem is a type of interaction. Secondly, with respect to absolute magnitude sign, the direction of the force applied in the various stages of the base vibration, and the forces applied at any given time are nonlinear. Therefore, numerical methods are usually used to solve the motion equations of this type of structures. To use Morrison equation it is necessary to use one of the wave theories. Various theories have been proposed for the waves, such as linear wave theory (Figure 1), Stokes theory and the theory of the trocoid wave, and we have used Stokes wave theory in this paper.

T = Wave period
K = Wave number
ω = Frequency of wave angle
H = Wave amplitude
L = Wavelength
C = Wave propagation speed

These quantities are linked by the following relationships:

$$\omega = \frac{2\pi}{T} \quad ; \quad K = \frac{2\pi}{L} \quad ; \quad \omega = \frac{2\pi}{T}$$

Wave velocity

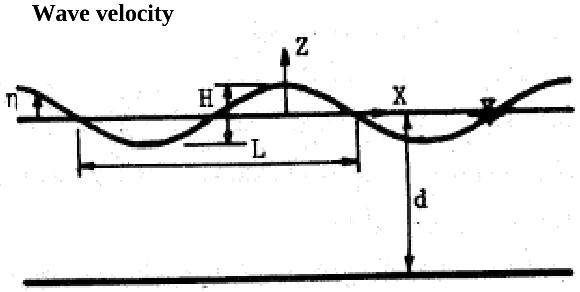

Figure 1. Water level at the moment t = 0 and introducing different wave quantities

In 1950, Morrison et al., assuming pryrionic nature of the waves are and the absence of the flow of the sea, by presenting a horizontal force model of the fluid in unbreakable waves based on a vertical cylinder based on the linear composition calculated inertia and drag:

$$F = fd + fi = 0.5PCD.D|u|u + pCM \frac{\pi D2}{4} \qquad (1)$$

where: F is the force perpendicular to the length of the vertical cylinder, u and u' are, respectively, the horizontal elements of velocity and the values of the particles of water, Cd and Cm, are drag and inertia coefficients, ρ is the mass density of water and D is the cylinder diameter. The inertia component of the Morrison equation is proportional to the horizontal component of the particle acceleration and is subjected to a non-slip field. The interaction of the member with the accelerated fluid causes the particles of water to pass through the cylinder at first and gain accelerating acceleration and then their acceleration reduces slowly. Such a reaction can cause inertia. Such a reaction causes an inertial force. Drag speed is also proportional to the horizontal mass of the particle velocity. This velocity is due to vertical or rotational flows.

Use of Stokes's fifth-order theory to solve the Morrison equation.

In this theory, using kinematics of water particle using two characteristics of the amplitude and period of the wave, the following relationships are determined:

$$n(x.z.t) = \frac{1}{k}\sum_{i=1}^{5} \binom{n}{k} \beta i \cos(kx - \omega t) \quad (2)$$

$$u(x.z.t) = \frac{\partial \emptyset}{\partial x} = cE + \frac{\sqrt{gk\tanh kh}}{k} x * \sum_{i=1}^{5} i a i \cosh ik(z+d) \cos i(kx - \omega t) \quad (3)$$

$$w(x.z.t) = \frac{\partial \emptyset}{\partial z} = \frac{\sqrt{gk\tanh kh}}{k} x * \sum_{i=1}^{5} i a i \sinh ik i(z+d) \sin i(kx - \omega t) \quad (4)$$

$$ax(x.z.t)^{\uparrow} = (\partial \emptyset)/\partial t = \omega \sqrt{(gk \tanh kh)}/k\, x * \sum_{\downarrow}(i=1)^{\uparrow}5 \; [i2ai \cosh ik \; [(z+d \quad (5)$$

$$az(x.z.t)^{\uparrow} = \partial w/\partial t = \omega \sqrt{(gk \tanh kh)}/k\, x * \sum_{\downarrow}(i=1)^{\uparrow}5 \; [i2ai \sinh ik \; [(z+d) \quad (6)$$

where: $\emptyset$ is the velocity potential function, h is the wave height, C_E is the average uniform flow, and A_{ij}, B_{ij}, and a_i are coefficients dependent on kd (k wave number and depth water depth), all of which are available from source (Sharan, 1987).

2. MATERIALS AND METHODS

The analytical model used is basically considered to be the bottom part of the soil and part of it in the water. In the upper part of the mass is the center of mass of the deck, which is completely prevented from rotating motion at that point so that the deceleration effects of the deck are based on the basis. The base consists of a set of elements of the beam and the soil softness effects, taking into account the dynamic hardness for the basis for the equations introduced. In order to reduce the computational volume, only one of the bases of the pier was considered. In this study, we will examine the effects of the load of waves first alone and then with the simultaneous loading of the earthquake with Tabas and Northrich earthquakes on the metal base of the pier. We will use ANSYS software to model it, where the general mode of the model and wave define is visible in Figure 2.

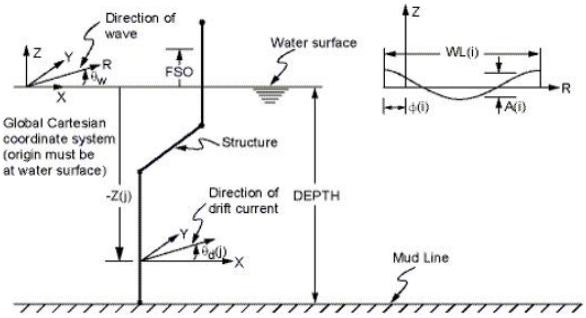

Figure 2. General geometric characteristics of the element with consideration of the height of the sea

To examine the bases of the pier in ANSYS software, PIPE 259 element is used (Figure 3) to display the speed profile view. Modeled steel pipe in this research has external diameter of 0.6m, thickness of 0.03m, a metal tube of elastic modulus steel with a density of 7850 kg/m3.

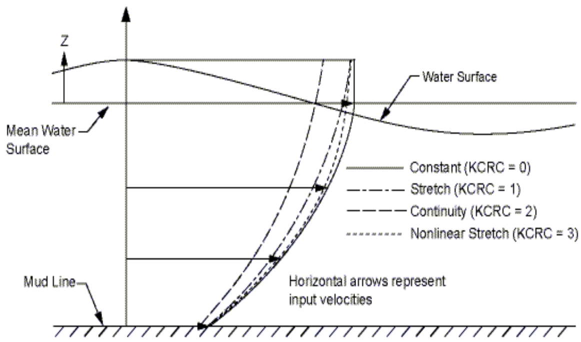

Figure 3. Profile view of the wave velocity around pipe 259

Drag coefficient 0.7 and coefficient of inertia 2.1 of pipes are against sea waves. The total length of this base is 25 meters, 22 meters of which is in the seawater with a density of 1025 kg/m3 with waves and earthquakes to the characteristics (Table 4).

Table 4. Features of the waves

Earthquake record	Sea wave height (m)	Wave period (s)	Sea height (m)	Height of the pier under study (m)	Model
-	2	10	22	25	M1
-	1	10	23	25	M2
-	1.5	10	22	25	M3
Nothrich	2	10	22	25	M4
Tabas	2	10	22	25	M5

The convergence of the answers should be considered in order to obtain the correct response of the structure. For this purpose, the change of parameters for a different wave is shown with the number of meshes in figures and tables. As shown in the figures and tables below (Figures 5-10, Tables 11-13), the node is constant with increasing wave height, as well as with the addition of Tabas and Northwich records, and the values of the parameter under consideration are very small.

The results of the validation of the results obtained from wave analysis are compared with other researchers. To ensure the results are presented, the results are (Nagipour et. Al., 2008) and (Malek and Keinia, 2007).

3. CONCLUSIONS

The following figures represent the amount of displacement, the amount of acceleration, and the amount of reciprocal response.

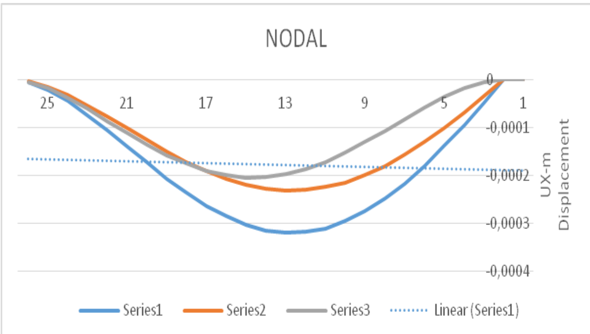

Figure 5. Displacement Chart for Model 1 to 3

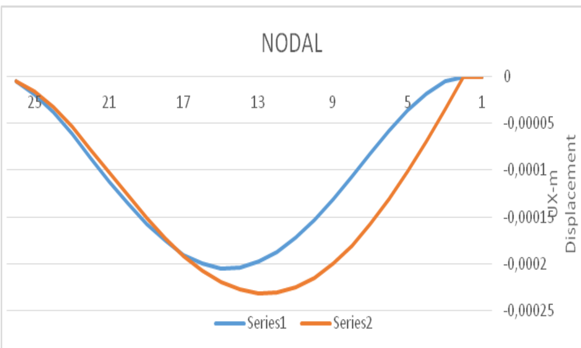

Figure 6. Chart diagram for the Tabas and Northwich model

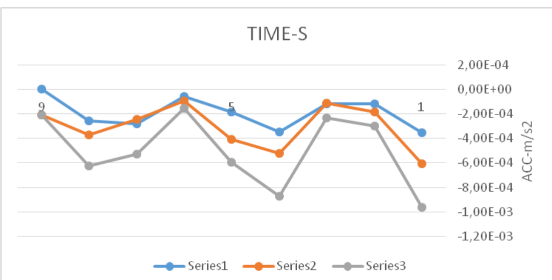

Figure 7. Node acceleration charts for models 1 to 3

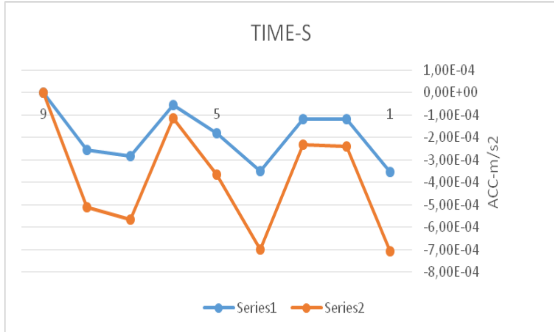

Figure 8. Node acceleration graphs for the Tabas and Northwich models

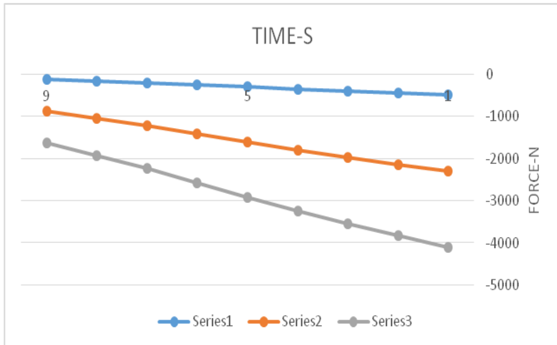

Figure 9. Rear force diagram for model 1 to 3

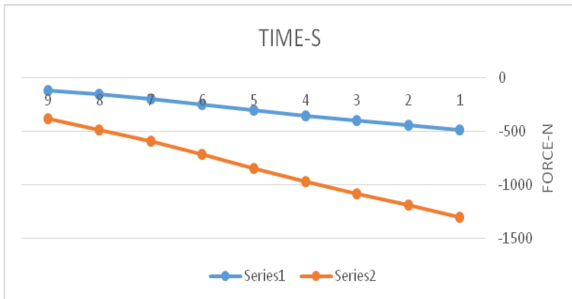

Figure 10. Rear force chart for the Tabas and North Ridge model

Table 11. The value of displacement of nodes 13 for model 1 to 5

Node	Dmax (100s)	Dmax (1s)	Model
13	0.16365e-03	0.31971e-03	1
13	0.16365e-03	0.31971e-03	2
13	0.16365e-03	0.31971e-03	3
15	9.17133e-03	0.20474e-03	4
5	0.23207e-03	0.71730e-03	13

Table 12. Acceleration value for the node with the most recent state change

Model	AX(100S)	Node
1	5.04E-07	13
2	-2.11E-04	13
3	5.04E-07	13
4	5.11E-07	15
5	5.11E-07	13

Table 13. The force of the response of the recurrence in node number one

Model	FX(100s)	Node
1	-116.992	1
2	-117.444	1
3	-266.203	1
4	-760.176	1
5	-445.082	1

The basic problem in the dynamic analysis of structures is based the nonlinearity of hydrodynamic forces on the one hand and the compatibility of these forces with the relative velocity of the water and the base on the other. An applied example of this model is the dynamic behavior of the quay under the influence of waves and earthquakes that have been studied and analyzed in this research.

The analytical model used intended to in the water and soil. In the upper part of the base is a central mass that prevents rotating motion at that point in full so that the effect of the high slope of the deck is based on the order.

Under different loading, the most horizontal displacement in the midpoint of the bases is gradually reduced from the middle to the extremity of the sides.

Horizontal displacements from characteristic wave loads are equal in modes 1, 2 and 3, and in modes.

The earthquake affects more than the other and the highest displacement is in mode 4 with the Tabas earthquake record. As in the present calculations, the effects of transverse forces and the effects of the wave reflection phenomenon are not interfered; there may be errors in the estimation of force for using Stokes theory in this problem.

In Table 11-13, the reciprocal forces of reliance has sometimes been shown that this value is almost limitless for 1 to 3 modalities, which increases with the increase in wave height, but with the interference of the forces generated by the earthquake, this increase is significant.

The main issue in the investigation of the behavior of the pier distinguishing it from other structures is water around the bases. The presence of water not only results in hydroreformed forces coming from the waves on the bases but also affects the vibration of the pier under the impact of the earthquake. The acceleration rate for the node with the highest displacement, according to the table 12, shows that the acceleration in all states is approximately equal and the node acceleration (base elements) is dependent on the kinematics of water particles (waves).

The amount of node displacement due to the force of the waves and the earthquake, especially in the middle part of the structure, may cause excessive stress in the structures in waves with higher altitude and periodicity and, in the end, cause early extinction and irreparable damage. In this research, a method for analyzing the amount of displacement, acceleration and recoil force was presented by ANSYS software. As outlined in the output charts, the amount of these parameters in the direction of wave propagation is more than the others due to the flow of water and the force generated by the current and waves.

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