University of Tabriz

Journal of Civil and Environmental Engineering
Volume 49 (2019), Issue 1 (Spring), 11-21

EXTENDED ABSTRACT

Investigating the Effects of Combined Tuned Liquid Damper (CTLD) on Dynamic Behavior of Offshore Jacket-Type Platforms

Hamid Ahmadi [a,*], Hossein Eyvazoghli [b], Mohammad Ali Lotfollahi-Yaghin [a]

[a] *Faculty of Civil Engineering, University of Tabriz, Tabriz 5166616471, Iran*

[b] *Faculty of Civil Engineering, Iran University of Science and Technology, Tehran 16844, Iran*

Received: 17 February 2018; **Accepted:** 20 October 2018

Keywords:
Offshore jacket-type platforms, Combined tuned liquid damper (CTLD), Dynamic analysis, Passive control.

1. Introduction

In the present paper, the efficiency of combined tuned liquid damper (CTLD) in controlling the dynamic responses of offshore jacket platforms under the earthquake and sea wave excitation is investigated. This type of damping system consists of one or more tanks containing a fluid, generally water or oil, which can be installed on the topside (superstructure) of the platform. During the excitation, hydrodynamic action induced by the sloshing of the water in the tank acts as a resistant force against the vibration and controls the structural response. In fact, due to the oscillation of the structure, the fluid inside the tank begins to oscillate in the opposite direction. During this process, most part of the fluid has a wave-like oscillatory motion, while the part adjacent to the tank's floor experiences a rigid-type displacement and exerts impact pressures to the tank's walls. In order to attain maximum decrease in the structural response, the oscillation frequency of the fluid inside the tank should be near the natural frequency of the structural free vibration which can be determined by performing a modal analysis. Hence, one of the objectives of the present study is to adjust the frequency of fluid's oscillation based on the natural frequency of the jacket structure. In other words, the aim is to find a frequency range in which the maximum decrease can be achieved in the amplitude of structural responses. In this research, using the FE software ANSYS, a jacket-type platform having dimensions appropriate for the Persian Gulf climate (case study: SPD1 platform) was modeled and then dynamically analyzed by the modal and time-history approaches subjected to the records of El Centro and Tabas earthquakes as well as 10 cases of wave loading with different height and period. The CTLD system was optimally designed and after the verification of FE results, the dynamic responses of the jacket-type platform with and without CTLDs were compared.

2. FE modeling and analysis

2.1. Modeling of the jacket

To model the jacket, the elements which are capable of determining hydrostatic and hydrodynamic effects of waves and added mass should be used. Element PIPE59 of ANSYS software has this ability. Inertia and drag coefficient were assumed 2.0 and 0.7, respectively. To add the wave loading, *Water Table* option in characteristics part of PIPE59 was used.

2.2. Modeling of piles

If the goal of analyzing a stationed jacket-type platform is to investigate the behavior of the whole structure, simple models can be used to consider the interactions between soil and piles. One of these simplified methods

* Corresponding Author
E-mail addresses: h-ahmadi@tabrizu.ac.ir (Hamid Ahmadi), h_eyvazoghli@civileng.iust.ac.ir (Hossein Eyvazoghli), lotfollahi@tabrizu.ac.ir (Mohammad Ali Lotfollahi-Yaghin).

is the Equivalent Length method. In this research and based on previous researches, the length of penetrated pile in soil was assumed to be 12*D* which was nearly 16.5m. Element PIPE16 was used to model the piles. Piles were modeled inside the legs, for the piles and legs have the same behavior under implemented forces. Similarly, all the pile nodes were coupled with base nodes in horizontal direction.

2.3. Modeling of the deck

Platform deck of SPD1 was modeled in three stories in a way that the stories heights from water level were 13, 17.5, and 21m, respectively. Elements PIPE16 and SHELL63 were used to model the platform deck. Platform deck system is a portal frame with no braces. Element PIPE16 was used to model the deck legs. Similarly, the whole weight of equipment on the deck was considered as distributed load using element SHELL63.

2.4. Modeling of CTLDs

To increase the effect of tuned liquid dampers on decreasing the vibration of structure, the first mode frequency of the liquid inside the tank should be equal to the main frequency of the structure vibration. In this research, to design the tuned liquid dampers and to determine the parameter values effective on its function, modal analysis was done on platform SPD1 and the first mode frequency was calculated as 0.483Hz.

The water level inside the tank was assumed to be 0.5m to determine the dimensions of the liquid tank (Lotfollahi-Yaghin et al., 2016). Then, having set the vibration frequency as 0.483Hz, the length of the tank was determined to be 3m. Afterwards, two tanks with the dimensions of 3x3x3m were modeled in ANSYS with the water level of 1.5m inside the tanks.

Element SHELL63 was used to model the tank and connector. Similarly, element FLUID80 was used to model the liquid inside the tank and connector. Elasticity modulus assumed for element FLUID80 is the bulk modulus of water. To include the interaction between tank and fluid, fluid and tank nodes matched on one another were coupled in vertical direction to the tank wall.

2.5. Wave and earthquake loading

In this survey, a set of time-series analyses was conducted on the platform under wave and earthquake loads. The goal of using CTLDs was to decrease the structural response to both wave and earthquake loads. In the present research, 10 cases were considered for the wave characteristics: Two wave heights of 9.7 and 12.2m; and five periods of 8, 9, 10, 11, and 12s. Stokes wave theory was implemented.

Two earthquake records were used and implemented as lateral load on the base-level of the structure. The used acceleration records are Tabas earthquake in Iran (1978) and El Centro earthquake in the US (1940). As the goal of this research was only to compare the relative responses of the structure, mentioned records are assumed to have their maximum values all the time with the maximum surface acceleration value of 0.35*g*.

3. Results and discussion

3.1. Modal analysis

To determine the mode shapes and natural frequencies of the platform vibration, modal analysis was conducted on the FE model of the platform SPD1 without CTLD. The frequency results were used for verification of the FE model, designing of CTLD system, and defining Rayleigh damping in analyzing the time history.

Having compared first ten generated frequencies of the model with the frequencies of the platform SPD1, acquired from Bargi et al. (2011), it was then shown that the model has acceptable accuracy. Moreover, the results indicate that there is a fine similarity between the results from the first two modes of the real platform and the model. However, the differences tend to increase in higher frequencies, the reason of which, according to Bargi et al. (2011), is the modeling of piles using equivalent length technique.

3.2. Specifying the state of the connection

First off, to determine the level of decrease in structure response with respect to the condition that there is no damper in the structure, two conditions were considered for the structure using CTLD. In the first condition, there was a connection between the two tanks where in the second condition, the connection between the tanks was blocked. In these conditions, the modeling was done for two different loading: 1) Loadings of Tabas earthquake, and 2) A wave with the height of 12.2m and period of 10s.

Table 1. The maximum amount of displacement decrease in two CTLD conditions (with and without connection)

Loading	CTLD with open connection	CTLD without connection
Tabas earthquake	9.41%	11.36%
Wave (H = 12.2m, T = 10s)	12.67%	8.55%

According to the acquired data presented in Table 1, it was shown that the CTLD system leads to a decrease in structure response in both situations—the connection between the tanks and without connection. The decrease in structure response under the earthquake load and with blocked connection was higher, while under the wave loading, the displacement was lower in connection condition between tanks.

3.3. CTLD effect on the acceleration at the highest platform elevation

The level of acceleration decrease in upper deck of the platform under wave force with different heights (9.7 and 12.2m) and different periods (8, 9, 10, 11, and 12s) was investigated in this research using CTLD (with connection). Results assert that by using this system, the upper deck of the platform experiences much less acceleration. The maximum amount of acceleration decrease in the upper deck of the platform SPD1, which was under the wave force with the wave height of 12.2m and period of 9s, was 22%.

4. Conclusions

In this research, a jacket-type platform with proportional dimensions for Persian Gulf (platform SPD1 as case study) was modeled with FE software ANSYS under loading of wave and earthquake in two conditions of with and without CTLD. Modal analysis and time history analyses were also conducted in this research. Having verified the model and designed the CTLD system, structure behavior with and without CTLD was investigated. Acquired results can be used to upgrade the seismic feature of present platforms as well as the new ones.

5. References

Bargi Kh, Hosseini SR, Tadayon MH, Sharifian H, "Seismic response of a typical fixed jacket-type offshore platform (SPD1) under sea waves", Open Journal of Marine Science, 2011, 1 (2), 36-42.

Lotfollahi-Yaghin MA, Ahmadi H, Tafakhor H, "Seismic response of an offshore jacket-type platform incorporated with tuned liquid dampers", Advances in Structural Engineering, 2016, 19 (2), 227-238.