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Seismic Response Control of Offshore Jacket Platform with Friction Damper

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Abstract— The seismic-induced dynamic force is one of the most important excitations to be dealt with in the design of offshore jacket platforms. In order to perform a reliable design of a platform, it is important to obtain an exact evaluation of its dynamic response but also to examine the ways of reducing the response. The safety of the platforms from seismic-induced vibration can usually be ensured by increasing their stiffness so as to shift their natural frequencies away from the resonating frequencies. However, this approach is generally costly requiring excessive construction material. An alternative approach is to implement active or passive control mechanisms to regulate the structural motion as desired. An active control mechanism can be effective over a wide frequency range with the desired frequency reduction in the dynamic response. The active control approach is now of current concern to many researchers and there are several attempts exploring its application to offshore structures. Passive control mechanisms do not require an external energy. However, very few studies are reported on the effectiveness of passive control system with added dampers in controlling the response of offshore platforms. This thesis covers the response of offshore jacket platforms installed with a passive energy dissipation device, friction damper. The performance of friction dampers to mitigate the seismic-induced vibrations in jacket-type offshore platforms has been investigated. An analytical model of a typical platform, located in Mumbai High oil fields is developed using the SACS software. Spectral Earthquake analysis has been performed for this model to evaluate the seismic responses, with the friction dampers to dissipate the seismic induced vibrations of the platforms. The modal mass determines the modal response for an earthquake excitation represented by a design spectrum. The analysis results clearly show that the maximum responses such as base shear and displacement in a direction depends on the dominating mode in that direction. Hence it can be asserted that the additional damper adds substantial damping to the structure and thus favourably control the response of platform structure.

Index Terms— Offshore jacket platform, Seismic induced-vibration, Active control, Passive control, Friction damper, SACS software, Spectral earthquake analysis.

1 Introduction

STUDIES about the steel jacket offshore structures has demonstrated that seismic forces were not given much importance in the design process.Seismic forces should be considered in platform design for areas that are determined to be seismically active. Areas are considered seismically active on the basis of previous records of earthquake activity, both in frequency of occurrence and in magnitude. Seismic activity of an area for purposes of design of offshore structures is rated in terms of possible severity of damage to these structures. Both strength and ductility requirements are included for the design of platforms. Strength requirements are intended to provide a platform which is adequately sized for strength and stiffness to ensure no significant structural damage for the level of earthquake shaking which has a reasonable likelihood of not being exceeded during the life of the structure. The ductility requirements are intended to ensure that the platform has sufficient reserve capacity to prevent its collapse during rare intense earthquake motions, although structural damage may occur.

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The safety of the structures from earthquakes can usually be ensured by increasing their stiffness so as to shift their natural frequencies away from the resonating frequencies. However, this approach is generally costly requiring excessive construction material. An alternative approach is to implement a passive or active control mechanism to regulate the structural motion as desired. Passive control mechanisms do not require an external energy but they have an inherent limitation. On the other hand, an active control mechanism can be effective over a wide frequency range with the desired frequency reduction in the dynamic response. The active control approach is now of current concern to many researchers and there are several attempts exploring its application to offshore structures. However very few studies are reported on the effectiveness of passive control system with added dampers in controlling the response of offshore platforms under a parametric variation to study the influence of important system parameters and comparative performance of dampers.

There had been studies regarding the control of wave induced vibration of an offshore steel platform using energy dissipation devices such as viscoelastic, viscous and friction dampers. The present work is intended to study the earthquake induced vibration control of jacket platforms using friction damper.

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Friction dampers are passive control devices with an effective performance in energy dissipation including relatively low cost and ease of installation. The displacement-dependency of the energy dissipation rate in friction dampers is a major difference between these and other types of damping device. Their resultant damping force is independent of the velocity response of the structure and the frequency content of excitation sand this makes them suitable for low frequency excitations, such as sea wave loading. Highly nonlinear and force limited action is the dominant characteristic of these devices. Diversiform friction dampers with various configurations have been invented and utilized for vibration control applications with a few practical applications against seismic excitations.

2 Objectives

The main objective of the study to compare the seismic response of the steel jacket offshore structure with and without friction damper.

3 Descriptions Of Model

In the present study two models of regular steel offshore jacket platforms with and without friction damper were analysed using the SACS software. Pile-soil interaction is included. The modelling details of considered platform configuration are given in Tables 1,2 and 3.

TABLE 1 MATERIAL PROPERTIES

Density, ϱ (kg/m^3)	7850
Young's modulus, E (Pa)	$2.1*10^{11}$
Poisson's ratio, ν	0.3
Thermal expansion coefficient, α	$1.2*10^{-5}$ /^{0}C

TABLE 2 THE MATERIAL SELECTION FOR THE STRUCTURAL STEEL MEMBERS

Structural elements	Specified minimum Yield strength (MPa)
Legs	420
Primary members	420
Secondary members	355
Piles	420

TABLE 3 STRUCTURAL MEMBERS

Member	Outer Diameter (cm)	Wall thickness (cm)
Jacket leg	106.70	3.5
Pile	92.5	2.5
Braces	41-66	1.6-2.5
Wishbone	92.5	2.5

4 Models Considered For Analysis

Following two models are considered and are analysed using SACS software. Spectral Earthquake analysis is used for the analysis of the models.

1: Jacket platform without friction damper.

2: Jacket platform with friction damper.

Spectral Earthquake analysis is performed in SACS 5.6 V8i. Response spectrum from the API RP2A code is used for the analysis. Parameters like base shear, fundamental frequency of vibration and displacement are studied. These values are then compared to obtain the conclusion that wether the friction damper is effective in controlling seismic vibration or not.

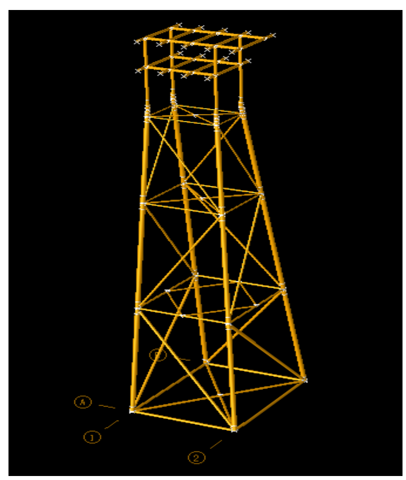

Fig 1 Jacket platform without friction damper

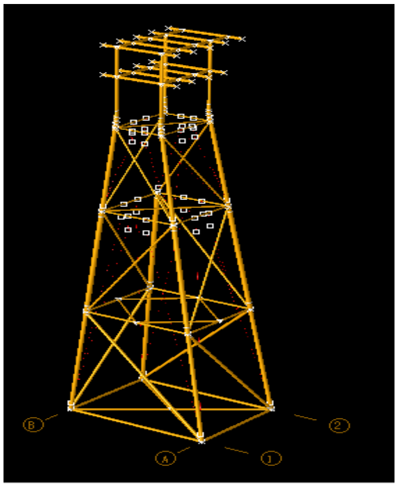

Fig 2 Jacket platform with friction damper

5 Results And Discussion

The modelling and seismic analysis of the platforms was carried out using the software SACS 5.6 V8i. The results obtained are tabulated below. The parameters which are to be studied are frequency, displacement, base shear.

5.1 Fundamental Period:

Period for both models are shown in table below:

Table 4 Fundamental Period Of Platform Without Damper

Mode	X-direction (sec)	Y-direction (sec)	Z-direction (csec)
1	2.78	2.85	2.78
2	2.78	2.78	2.78
3	2.08	2.08	2.08

Table 5 Fundamental Period Of Platform With Damper

Mode	X-direction (sec)	Y-direction (sec)	Z-direction (sec)
1	1.95	2.00	1.95
2	1.95	1.95	1.95
3	1.47	1.47	1.47

Jacket platform with friction damper has comparatively high frequency i.e. the least fundamental period of vibration among two the models. The reduction in fundamental period of TFB when compared with framed building is nearly 70%.

5.2 Base Shear

Base shear for both models are shown in table below:

Table 6 Base Shear Of Platform Without Damper

Mode	X-direction (kN)	Y-direction (kN)	Z-direction (kN)
1	1194.926	925.897	6.485
2	91.637	209.822	2.339
3	7.842	77.621	2.086

Table 7 Base Shear Of Platform With Damper

Mode	X-direction (kN)	Y-direction (kN)	Z-direction (kN)
1	1086.935	881.797	4.123
2	93.421	214.204	2.339
3	4.928	77.621	2.317

The base shears of abth models are compared in this section. The results show that the base shear values decrease in most of the cases, though there is an increase in some cases. But the increase is very less.

5.3 Deck Displacement

Deck displacement for both models are shown in table below:

Table 8 Deck Displacement Of Platform Without Damper

Mode	X-direction (m)	Y-direction (m)	Z-direction (m)
1	0.304	0.020	0.0002
2	0.036	0.368	0.0001
3	0.0004	0.110	0.0001

Table 9 Deck displacement of platform with damper

Mode	X-direction (m)	Y-direction (m)	Z-direction (m)
1	0.2031	0.012	0.0001
2	0.0222	0.219	0.0001
3	0.0003	0.070	0.0001

From the above tables, it is observed that the displacements reduce by around 60% when the friction damper is introduced.

6 Summary And Conclusion

A typical four-legged jacket structure in Mumbai High is modeled using SACS software with and without friction damper. Both models are analyzed by spectral earthquake analysis method. Friction damper is linearly dependent on the displacement amplitude. Spectral earthquake analysis results show that the use of friction damper reduces target displacement of the structure. Due to the low redundancy of jacket platform structures, the strength of these structures can decrease suddenly and the use of friction damper systems can be extremely useful. This study was undertaken for seismic load data from API code. Analysis results show that for wide range of record acceleration, friction damper greatly reduces deck displacement. It is observed that for large record accelerations structure behavior becomes highly nonlinear and the performance of the friction damper for response reduction increases (for example up to 65% deck displacement reductions). The modal base shear values obtained for X-direction input acceleration, the first mode has the maximum contribution to X-base shear and for Y-acceleration, second mode has maximum contribution to Y-shear. The displacements are also based on the modal base shear. The studies reported clearly shows that this control system presents a practical alternative for control of vibration due to seismic load. The device is economical and can be easily installed and protects structures from structural and non-structural damages in moderate and severe earthquakes.

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