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# Study on the structural monitoring and early warning conditions of aging jacket platforms

Yougang Tang [a,b,*], Zhaoxi Qing [a,b], Longhuan Zhu [a,b], Ruoyu Zhang [a,b]

[a] State Key Laboratory of Hydraulic Engineering Simulation and Safety, Tianjin University, Tianjin 300072, PR China
[b] School of Civil Engineering, Tianjin University, Tianjin 300072, PR China

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ABSTRACT

In this paper, the structural monitoring methods and early warning conditions were proposed based on the characteristics of the aging jacket offshore platforms, including the monitoring and early warning condition of the displacement, the bearing loads of pile end and the platform subsidence. On the basis of pushover analysis, the curves of base shear force versus deck displacement were drawn. Furthermore, the anticipated risks were classified into three levels due to different deformations in the collapse process; the three level early warning conditions were established. A method of the monitoring of the bearing loads of pile end was put forward, with the calculating of the load transmission function. The early warning condition that the bearing loads of pile end should not exceed half of the ultimate pile capacity was provided based on API RP 2A-WSD. The long-term monitoring method of the platform subsidence was presented based on the calculating of the difference of elevation between any two pile tops. The early warning conditions considering the stress and tilt requirements were established. The monitoring method has been applied to a jacket offshore platform on the South China Sea, and the result illustrates the feasibility of this method.



## 1. Introduction

Many jacket offshore platforms in China have been approaching or exceeded their original design lives, and during their service time, they have been suffering the averages such as corrosion, subsidence, scouring, fatigue and accidental damages. Besides, in order to maximize the economic benefit, renovation projects, including additional conductors and topsides modification, are universally seen in most of offshore platforms. The real-time monitoring of the offshore platform is in urgent need to judge whether the offshore platforms are available to operate or not, and the early warning conditions are required to make contingency plans to ensure personnel security.

Mangal et al. (2001) adopted vibration responses due to impulse and relaxation for structural monitoring of offshore platforms. Nichols (2003) established a new method for monitoring the integrity of offshore structures using ambient excitation. Kianian et al. (2013) presented a damage detection method using frequency domain selective measurements and the proposed method was carried out on a two-dimensional jacket platform on the basis of numerical study. Xu et al. (2013) proposed sensitivity diagnose method based on the fact that some members of jacket platform are very sensitive to the damage of the structure. Liu et al. (2012) put forward a damage diagnosis method based on genetic algorithm, using an improved objective function according to the noise measurement and the characteristics of modal identification for offshore platform. Liu et al. (2011) detected the structural damages with different cases using genetic algorithm and mode strain energy method based on model tests. Ou et al. (2001) developed a real time safety monitoring system for offshore platform using corrected real time calculation model based on the environment monitoring. Wang et al. (2010) and Xu et al. (2008) proposed the long-term monitoring method of deck load and the variety of the upper load with fiber brag grating sensors. Wang et al. (2012) inspected the pile foundation bearing capacity of an offshore platform in Bohai Bay and had taken a one-year settlement monitoring for it. Setan and Othman (2006) monitored the subsidence of offshore platform using permanent GPS stations. But the accuracy of the method is relatively low, while the cost is relatively high. Wang et al. (2011) proposed a three-level subsidence monitoring method based on the soil compress characters and the subsidence harmful degrees, but the computing method especially for the settlement has not been

* Corresponding author at: School of Civil Engineering, Tianjin University, Tianjin 300072, PR China.
Tel.: +862227406074-818; fax: +862287890325.
*E-mail address:* tangyougang_td@163.com (Y. Tang).

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given. Up to now, a perfect monitoring method for offshore platforms has not been established, and neither has the uniform standard for the warning conditions correspondingly.

In the monitoring process, how to gain the bearing loads of pile end, as well as the subsidence? And what early warning conditions shall be chosen to evaluate the service state of the platform after having gained the relative monitoring data? The solutions of these questions are crucial to the security of aging offshore platform. In order to solve these problems, a monitoring system for the integrity of offshore platforms is developed, including the monitoring of the displacements, the bearing loads of pile end and the settlements and the early warning mechanism correspondingly. The application performed very well on a jacket platform on the South China Sea.

## 2. Displacement monitoring and warning condition

### 2.1. Ultimate strength analysis

Ultimate strength analysis was performed to research the relationship between the deck displacements and the corresponding deformations in the structure. Accordingly, the deck displacements were monitored to detect the deformations of the offshore platform, and simultaneously different level warning conditions would be issued based on different potential risk of the deformations such as member initial yielding, pile initial yielding, pile pullout or pile punch-through, and last collapse.

Pushover analysis (Zhu et al., 2014) is a common method to analyze the ultimate strength of the offshore platform. This method involves a single static load pattern corresponding to a particular choice of wave, current and wind. This load applied to the structure is typically increased monotonically up until the structure as a whole collapses or is pushed over. For each step, the nonlinear events such as joint flexibility and member plasticity will be concerned. The pile–soil interaction was also been considered in this paper.

The twelve directions shown in Fig. 1 were typical used for the pushover analysis, including broadside directions (90 and 270 degree), longitudinal directions (0 and 180 degree), and diagonal directions (35, 49, 131, 145, 215, 229, 311 and 325 degree). These twelve attack directions were chosen for their storm severity. The pile–soil interaction was taken into account based on T–Z, P–Y, and Q–Z data, and the pile elements were included as plastic members.

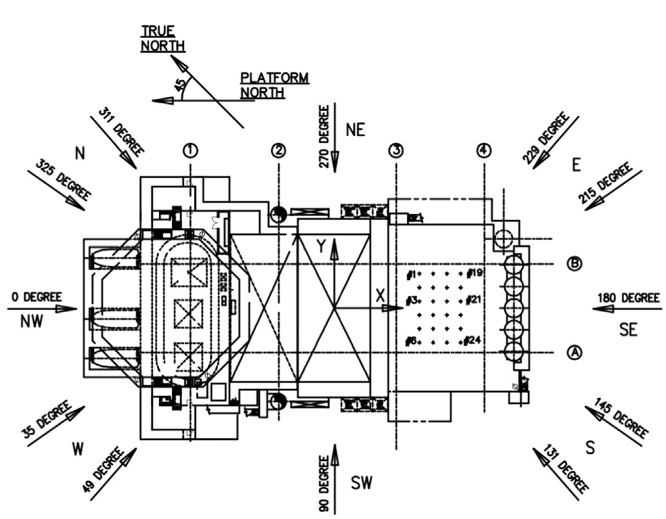


**Fig. 1.** Directions of pushover analysis.

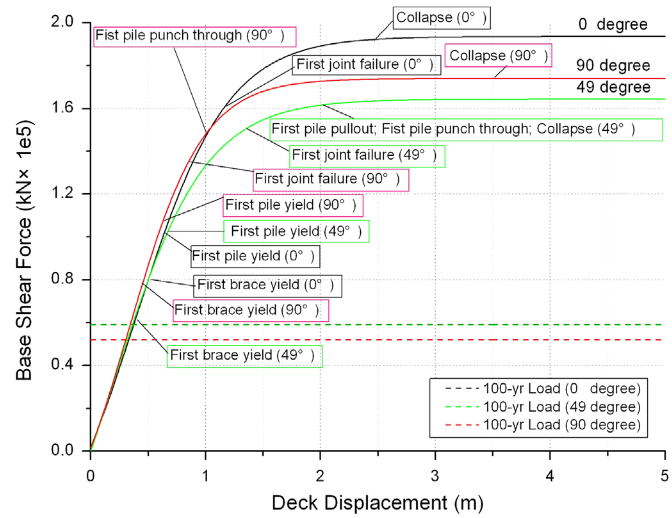


**Fig. 2.** Base shear force versus deck displacement.

### 2.2. Pushover analysis results

Fig. 2 shows the base shear forces plotted against the deck displacements for the three typical direction pushovers of 0, 49 and 90 degree. From the figure, the following observations can be made

In 0 degree direction: as the deck displacement value increases up to 0.527 m, the first brace starts yielding; and up to 0.673 m, the first pile begins yielding; and up to 1.172 m, the first joint failure occurs; and up to 2.511 m, the structure collapses.

In 49 degree direction: as the deck displacement value increases up to 0.401 m, the first brace starts yielding; and up to 0.664 m, the first pile begins yielding; and up to 1.365 m, the first joint failure occurs; and up to 2.020 m, the structure collapses.

In 90 degree direction: as the deck displacement value increases up to 0.445 m, the first brace starts yielding; and up to 0.633 m, the first pile begins yielding; and up to 0.850 m, the first joint failure occurs; and up to 3.491 m, the structure collapses.

### 2.3. Early warning conditions

According to the pushover analysis results aforementioned, as the load increases monotonically, the deck displacement increases correspondingly and the corresponding deformation occurs. The platform conditions of different deck displacements would be classified based on the fact that different deformations implicate different levels of risk or consequence. The first brace initial yield might result in local damage and weaken the local strength of the structure, which is defined as low class risk, and simultaneously, the early warning defined as Blue Pre-Warning would be issued. Similarly, the first pile initial yield is defined as middle class risk and corresponding Orange Pre-Warning would be issued, and the first joint failure is defined as high class risk and corresponding Red Pre-Warning would be issued, as listed in Table 1.

On the basis of the analysis stated above, the three-level warning conditions corresponding to the deck displacements reflecting the risk classes are established, as shown in Fig. 3. The Red Pre-Warning condition is conserved, since the ratio of the warning base shear force to the capacity (RWC) is ranged from 0.677(for 270 degree, broadside direction) to 0.893(for 35 degree, diagonal direction), quite lower than 1.0.