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EXPERIMENTAL RESEARCH ON FIXED JACKET OFF-SHORE PLATFORMS

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SUMMARY

The prototype test of two fixed pile-supported jacket off-shore platforms in Bohai Bay China in 1980 is presented in this paper. The results of test show that, the jacket structures are vibrated with complex space coupling vibrations under various dynamic excitations. Comparing the acceleration responses of tested jacket structure, we know that, the most significant effect on acceleration responses is the boat ramming, the secondary effect on it is the strong wind plus waves, the least effect on it is the rocket--type exciter.

INTRODUCTION

More than ten off-shore platforms have been constructed in the Bohai Bay China since sixty of 20th Century. The jacket platforms are used for the main type of structure, because the sea water depths are not more than several ten meters. The off-shore platforms are suffered more severe enviromental conditions than the structures standing on the land, such as wind, waves, current, earthquakes, icebergs, boat ramming, excitations of petro tapping machnies. A flare jacket built in the Bohai Bay was collapsed by iceberg excitation loads in early spring in 1977 (Ref. 1).

The prototype tests of the jacket off-shore platforms of No. 8 and No. 12 were carry out in 1980. The purposes of tests are to know dynamic characteristics, dynamic responses and behaviour of this type of the platforms under various dynamic excitations. After being tested, the eigen-values of main jacket structure of the No. 12 platform are calculated.

STRUCTURAL FEATURES OF PLATFORMS

No. 8 Platform The platform is located in the center part of the Bohai Bay. It consist of four parts, namely, oil-extracting-storage-tank platform, life-power platform, steel bridge with a span of 50 meters and one flare tower standing on the deck. The water depth of the platform site is 24.5 meters and the length of piles in the soil-layer is 31 meters. The structural scheme is shown in Fig. 1.

No. 12 Platform The platform is no far from No. 8 platform in the Bay. It consists of five parts, they are: drilling and oil-extracting platform, oil-storage-tank platform, test-drilling platform including one flare tower standing on the deck and two steel bridges with a span of 50 meters respectively. The water depth of the platform site is 25 meters and the length of piles in the soil-layer is 35 meters. The standard scheme is shown in Fig. 3.

Table 1. Test and Calculated Results of No.8 Platform

Structural Elements	Mode Shapes	Tape Records Freq.(Hz)	Light Records Freq.(Hz) Min.	Maj.	Vert.	Calculated Values Freq. (Hz)	Max. Amplitudes (M.M)	Notes
Oil-Drilling and Storage-Tank Platform	1	1.30	1.41 — 2.95	1.85 — 2.95			0.399	The translational displacement of the deck is Max.
	2	1.85						
	3	2.90						
	4	4.80						
	5	9.05						
	6	13.75						
	7	17.90						
Bridge	1	2.95 (1.3, 1.65)	3.13 (1.57)	1.69 (1.85)	3.05	2.66	0.124	The Max. vertical amplitude of the midle span of the bridge is 0.124M.M and the translational Max. Amplitude of the same point of the bridge is 0.205M.M the coupling frequencies of the bridge between two platforms are in the brackets
	2	5.05					0.205	
	3	6.25						
	4	7.50						
Life-Power platform	1	1.45	1.57 — 2.95	1.85 — 2.95				
	2	2.30						
	3	2.95						
	4	4.89						
	5	9.40						
	6	10.30						
	7	16.35						

TEST RESULTS

No. 8 Platform The results of tests are shown in Table 1 and Fig. 2 shows the results of acceleration records.

It can be seen from Table 1 and records of tests that:

1. There appear space coupling vibrations for the No. 8 platform which is composed of two individual platform and steel bridge. The frequency of coupling vibration is 2.95 Hz which is not only the third frequency of two platforms but equals to the first frequency of the bridge.

2. Some times there is overall translational coupling vibration in the longitudinal direction with frequency 1.85 Hz.

3. From recorded data of displacement responses along the height of platforms, we know that there are always different vibration phases and it is obvious that these are torsional vibrations under wind-waves excitations.

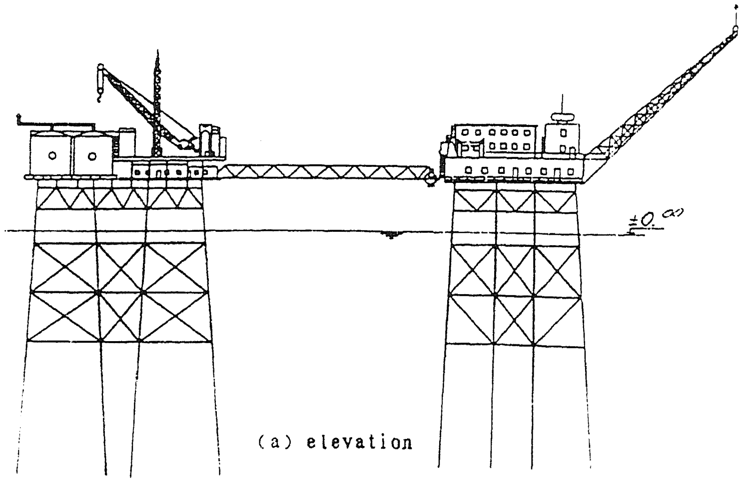
4. The amplitudes of pile top nearby the water level are about 2.5 times more than the amplitudes of the deck, this is because there are no braces between legs of the jacket.

5. In the vertical direction, observed frequency of the bridge 3.05 Hz closes to the calculated value 2.66 Hz.

Twelve accelerometers are set on the tops of piles and the dynamic characteristics, acceleration responses of two platforms are recorded. From Fig. 2 and recorded data we know that:

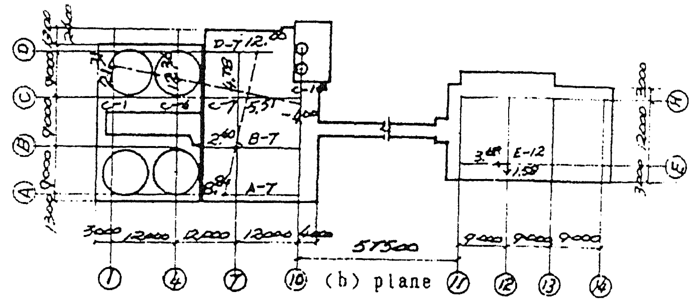
1. Two platforms and bridge are vibrated together and their dominant frequency is 2.95 Hz, which is coincident with the translation-torsion frequency.

2. Comparing the acceleration responses of platforms under various dyanmic excitations, we find that the most significant effect on responses is the boat ramming, a great effect on them is the strong wind-waves and a small effenct on them is the



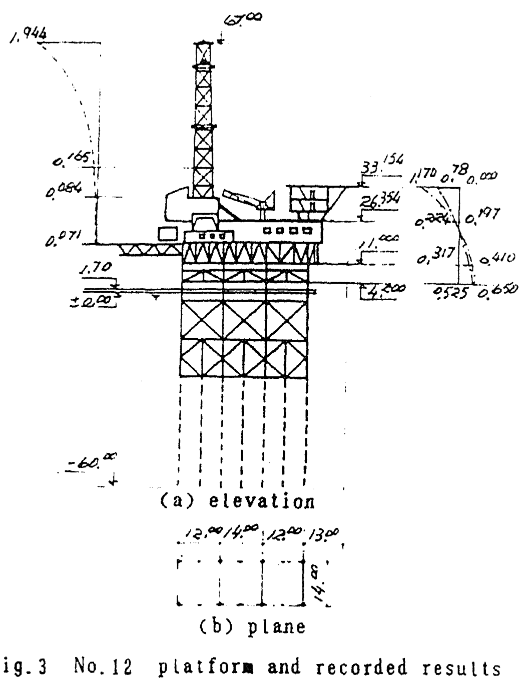
(a) elevation

Fig. 1 No. 8 Platform



(b) plane

Fig. 2 Recorded accelerations



(a) elevation

(b) plane

Fig. 3 No. 12 platform and recorded results

Table 2. Test and Calculated Results of No.12 Platform

Structural Elements	Mode Shapes	Tape Records Freq.(Hz)	Calculated Values Freq. (Hz)	Damping ratios (%)	Light Records Freq.(Hz)			Damping Rotios (%)	Max. Amplitudes (M.M)
					Min.	Maj.	Vert.		
Oil-Drilling and Extracting Platform	1	0.90	0.88	3.6	0.926	—	—	2.9	1.17
	2	1.05	0.88		0.964	1.03	4.36	2.6	0.78
	3	1.20	0.94		—				
	4	1.70	1.67		—				
	5	2.20	2.23		—				
	6	2.80	2.90		—				
	7	2.85	2.90		2.88				
	8	3.20	3.19		—				
	9	3.25	3.37						
Drilling Tower	1	1.00		3.0	1.11				1.94
	2	1.10			—				
	3	1.40			—				
	4	2.55			2.54				
	5	3.85							
	6	6.25							
Drilling operating board	1				4.54	—	—	4.4	1.89
No.1 Bridge	1				2.54	2.56	2.70	—	0.27
Oil-Storage-Tank Platfom	1	Platform			2.31	2.36			0.32
	1	Oil-Tank			1.95	1.99			
	1	Tank cover			4.00	4.00			
Test—Driling platfom	1	1.30			1.63	1.31			
	2	1.55							
	3	2.30							
	4	2.40							
	5	3.00							
	6	4.35							
Building	1	1.45							0.52
	2	1.55							
	3	2.45							
	4	2.60							
	5	2.95							
	6	4.00							
Flare Tower	1	1.35			1.83	1.23			3.52
	2	1.60							
	3	2.30							
	4	2.50							
	5	3.95							
	6	4.90							
No.2 Bridge	1				2.72	2.66	2.77		1.85 1.71

Notes:

The first mode frequency of the platform under the boat ramming is 0.926Hz and The mode frequencies under the wind-waves excitations are 0.964, 1.03, 4.36. The Max. Amplitude of the top of the Drilling tower under wind-waves excitations is 1.94M.M. Drilling platform and tank platform are connected by No.1 bridge. Test platform and Tank platform are connected by No.2 bridge. The periods of waves in the Bo hai Bay are between 5 and 22 seconds, but most of them are 10 to 15 seconds.

rocket-type exciter.

3. Two platforms and bridge are excited by micro wind-waves, it appears that each structural element is vibrated individually.

Two platforms and bridge are vibrated at same time with translation-torsional frequency of 2.95Hz when the excitation forces are larger, such as boat-ramming, strong wind-waves etc.

No. 12 Platform The results of tests and calculations are shown in the Fig. 3 and Table 2. It can be seen from this table and Fig. 3.

1. Drilling and oil-extracting platform

1) The calculated values of the first nine frequencies of the jacket structure are basically in agreement with the experimental data.

2) The main platform is vibrated with space torsional vibration whose frequency is 2.90 Hz and there is coupling vibration between drilling tower and No. 1 bridge with frequency 2.54 Hz.

3) From sea level to the top of building there appear different mode shapes, it is shown that the main platform vibrated with space torsional vibration also and the deformation shape of the drilling tower is similar to a hyperbola.

4) The first frequency of platform is 0.926 Hz under the boat ramming excitation and it is 0.969 Hz under the strong wind-waves excitation, but it is 1.0 Hz under the micro wind waves excitation. It is shows that, the more the excitation forces are large the more the period of the jacket structure is long.

5) The frequency of drilling bar is 4.54 Hz which approaches to the frequency 4.36 Hz of the platform in the vertical direction, so the resonance occurred, the lateral amplitude of the operating board increased suddenly. It reached 1.89mm, which nearly equals to the amplitude of the top of drilling tower--1.94mm.

6) Damping ratio Three methods are used for determination of the damping ratio of jacket structure. One is the free attenuation vibration of the platform after ellimination of the force of boat ramming, the other is free attenuation vibration after ellimination of the force of drilling bar and the third is the frequency spectrum analysis of micro-vibration records of the jacket structure. The test values of damping ratios are between 2.5% and 4.4% and the average value is 3.3%, most of them are nearby 3%.

2. Storage-tank platform. This platform is square on the plane and is supported by sixteen piles (4X4).

Four oil-tanks with the same volume are set on the deck of this platform.

1) The first frequencies of the platform in the two perpendicular direction are nearly same. They are 2.36 Hz and 2.31Hz respectively. Four oil-storage-tanks were empty during testing and in this case the frequencies in the two perpendicular direction nearly equal to each other also, they are 1.95Hz and 1.99Hz respectively but all covers of the tanks appear to be local vibrations with same frequency of 4.0Hz.

2) Both platforms and two bridges which connected with each other are coupling vibrations. The frequency of each bridge is about 3.0Hz which is nearly equivalent to the frequency of the other bridge, which supported on the No. 8 platform.

3. Test-drilling platform. Comparing with the experimental frequencies of platform,

building and flare tower, we find that the frequencies of them are nearly equal to each other. This fact shows different structural elements setting on the same support of jacket are vibrated with the same frequencies, which are controlled by the frequencies of load-carrying structure, even if they have themselves local frequencies.

According to the features of the jacket structure, substituting [M] and [K] in the free vibration equations and Program SAP5 is used on CIEMENS computer for calculation the first nine frequencies and mode shapes. The calculated results are in good agreement with the results of the prototype tests (Table 2 and Ref. 2).

CONCLUSIONS

1. Fixed pile-supported jacket off-shore platforms are vibrated with complex space modes under various dynamic excitations.

2. The prototype test shows that the more strong excitation force, the more long period of the structure and the periods of the structure are not constant in generally, the damages are frequent occurrence when the excitation forces come from boat ramming, thus we must pay attention to this force sufficiently in design.

3. The first frequnecy of jacket off-shore platform is not too low on an average is about one Hz or more, because the depth of seawater in Bohai Bay is no more than several ten meters, so the frequencies of the platform can not coincide with the frequencies of waves but can coincide with the frequencies of earthquakes, ice, facilities excitations. Therefore, the natural frequencies of the structure should not coincide with the frequencies of the exciting forces in design, so as not to occur resonance.

4. The frequencies of jacket structure calculated by dynamic analysis are in agreement with the results of prototype test, which show that considering the jacket structure as a whole space rigid frame is quite resonable.

5. In order to simplify calculation of the pile-soil interacion, the piles are considered as an equivalent beams fixed in the seabed soil and its clamp-built length is taken as six times the diameter of the pile. The results of prototype test show that the frequencies of the structure calculated by this method are correct.

6. The damping ratio of the pile-supported jacket structure is about 3%, this value may be used in the future design practice.

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