AMBIENT VIBRATION SURVEY OF A 325-METER HIGH MAST

by

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SYNOPSIS

The vibration characteristics of a 325-meter high mast were obtained by ambient vibration test with random signal data processing. There are data of frequencies up to the tenth mode and mode shape amplitudes as well as damping ratios up to the eighth mode, the average value of damping ratios is 0.8%. This is an efficient and convenient way of measuring the vibration characteristics of structures.

DESCRIPTION OF STRUCTURE

The tested steel mast is 325 meters in height. It is a triangular section structure with guy cables attached on five levels as shown in Fig.1. There are fifteen platforms along the mast, and those were used for setting instruments.

MEASUREMENT AND ANALYSIS

The ambient vibration signals were recorded in an analog tape recorder with recording time long enough in field and analysed through data processor in the laboratory.

The transducers were set on the following platforms: No.4(47.5-meter level), No.6(80-meter level), No.8(120-meter level), No.10(160-meter level), No.11(180-meter level), No.13 (240-meter level) and No.15(320-meter level).

In the data processing procedure, the method of the Fast Fourier Transform, transfer function and coherence function as well as changing tape speeds during reproducing were used to obtain the dynamic characteristics of the structure.

VIBRATION CHRACTERISTICS OF STRUCTURE

Frequency spectra. The exciting source of ambient vibration of this mast consists of two parts: wind and ground tremor. So the mast is a multi-input system. In this case, provided that the recording time is long enough, the spectrum of exciting source may be considered as white noise approximately. Under this condition, the Fourier transform or power spectrum $G_x(f)$ of time history of vibration of structure x(t) can be used to get the vibration characteristics of structure.

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For keeping the value of error of random signal within a certain range, it is also necessary for the recording time of single sample function to be long enough.

Fig.2 presents the spectra of displacement amplitudes along the EW direction, and those of NS direction are similar.

Vibration mode shapes. The amplitude values of each mode can be obtained from the amplitude-frequency curves. Due to the fact that the processor didn't give the phase-frequency curve directly, the phase-frequency characteristics of transfer function were used to determine the phases of each mode. For this purpose, the transfer function corresponding to every measuring point relative to a given fixed point had been obtained in advance.

For assessing the availability of the transfer function data, it is necessary first to take the coherence function $\gamma^2_{xy}(f)$

$$\gamma^2_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_x(f)\,G_y(f)}$$

$$0 \leqslant \gamma^2 \leqslant 1$$

The signal magnitudes of some frequency components of certain measuring points are so small that the noise level of those cases will be relatively high and the values of coherence function may be much smaller than unity. Therefore it is sometimes necessary to specify several "fixed points" for obtaining the available data of the transfer function in order to determine the phases of some modes.

The data of transfer function and coherence function obtained by the means as previously mentioned are also useful to judge which frequency reflects the vibration on the whole and which is due to the local vibration. Then the effects of local vibrations can be got rid of.

Table 1 and Table 2 indicate respectively the data of mode shapes of vibrations in EW and NS directions. Fig.3 and Fig.4 are the curves of shapes.

Damping ratios. When the recording time is long enough, the spectrum of input signals is close to that of white noise, so the damping ratio can be obtained directly from the spectrum diagram.

The mast have low frequencies and small damping ratios. For satisfying the specified accuracy, a nice resolving power has to be kept in the procedure of processing. The minimum value of frequency resolving bandwidth is 0.0109Hz, that is obviously unsatisfactory. For promoting the accuracy, the ratio B_e/B_r must be decreased. B_e is the resolving bandwidth and B_r is the half power point bandwidth.

For realizing that, low tape speed for signal recording and high speed for reproducing to the processor was taken in processing. If reproducing speed is k times the speed of recording, the half power point bandwidth will be k times the original value, thus the ratio B_e/B_r will be decreased. In this work k was chosen as 16, 8, 4, 2 and 1. At the same time, this method is also able to judge the selected resolving bandwidth whether it is small enough when the damping ratio of a certain frequency is determined.

Table 3 presents the data of damping ratios obtained with different values of speeds.

CONCLUSION

Ambient vibration survey is an available way of studying the natural characteristics of such structure as high mast, especially due to its convenience during field work. Data prodessing gives the reasonable results in practice.

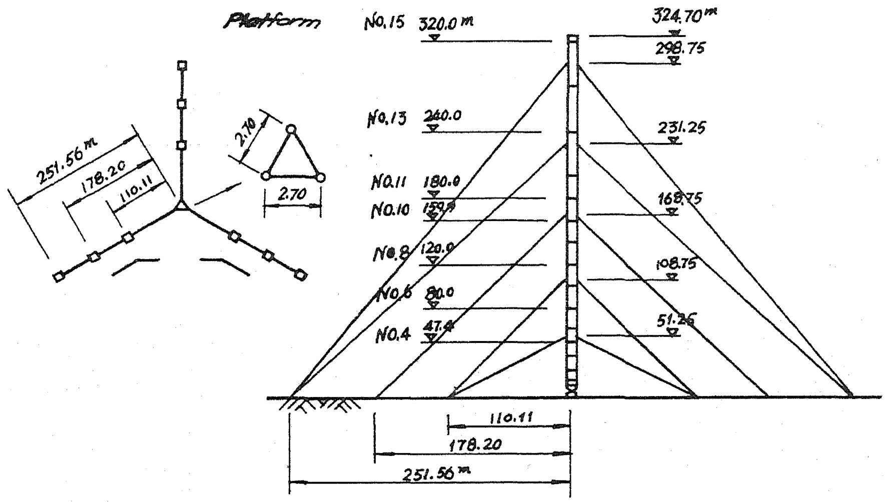

Fig 1(a) plan of Mast

Fig 1(b) Elevation of Mast

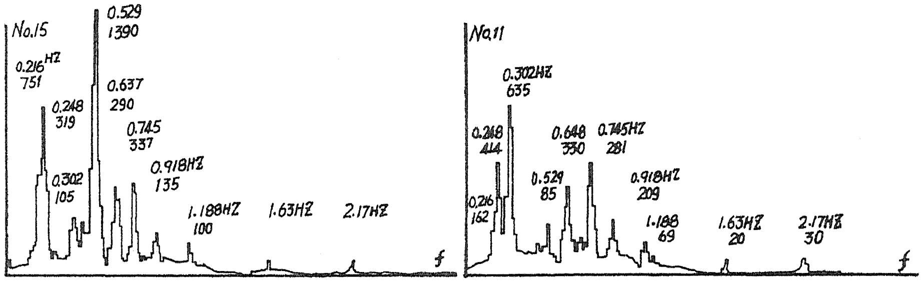

Fig. 2 Spectra of displacement amplitudes in EW direction

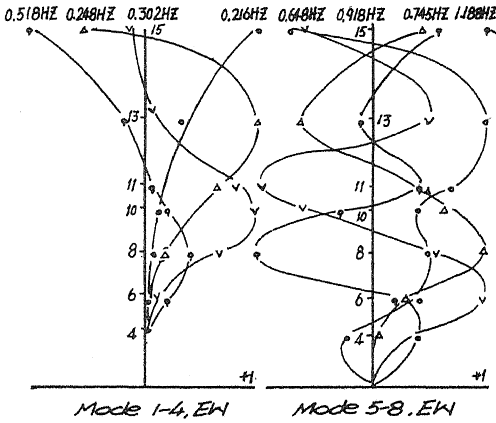

Fig. 3 Mode shapes in EW direction

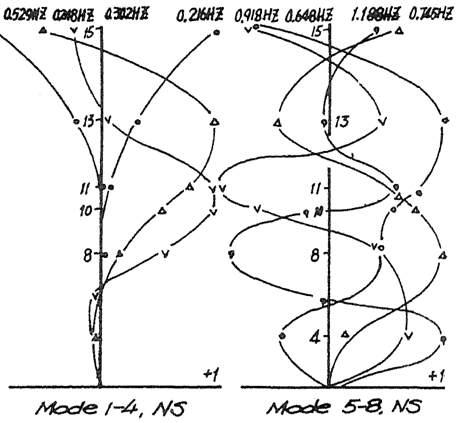

Fig. 4 Mode Shapes in NS direction

Table 1 Data of mode shape amplitudes in EW direction

Fre-quency	Measuring Points. level No.						
	No.4	No.6	No.8	No.10	No.11	No.13	No.15
0.216HZ	—	0.026	0.084	0.164	0.23	0.31	1
0.248	0.02	0.04	0.176	0.42	0.66	1	-0.51
0.302	0.02	0.10	0.66	1	0.81	0.09	-0.14
0.529	0.027	-0.17	-0.39	-0.175	-0.06	0.175	1
0.648	0.20	0.42	0.49	0.41	0.72	1	-0.72
0.745	0.064	0.29	1	0.62	0.49	-0.61	0.44
0.918	0.37	1	0.504	-0.59	-0.94	0.49	-0.63
1.188	-0.38	-0.23	1	0.264	-0.44	0.07	-0.57
1.63	0.90	1	0.67	0.67	0.67	0.77	0.90
2.17HZ	—	0.80	0.80	0.68	0.91	1	0.64

Table 2 Data of mode shape amplitudes in NS direction

Fre-quency	Measuring points. level No.					
	No.4	No.8	No.10	No.11	No.13	No.15
0.216HZ	—	0.034	—	0.046	0.32	1
0.248	-0.045	0.195	0.56	0.80	1	-0.50
0.302	-0.037	0.58	1	0.99	0.04	-0.23
0.529	0.01	-0.02	—	-0.05	0.19	1
0.648	-0.41	0.45	0.54	0.79	1	-0.65
0.745	0.134	1	0.754	0.62	-0.46	0.61
0.918	-0.71	-0.43	0.62	1	-0.45	0.69
1.188	1	-0.88	-0.20	0.55	-0.05	0.38
1.63	—	0.29	1	0.62	0.19	0.52
2.17HZ	—	0.70	0.17	1	0.97	0.55

Table 3 Damping ratios (%) correspond to different frequencies

Fre-quency	reproducing Tape speed				
	$V \times 1$	$V \times 2$	$V \times 4$	$V \times 8$	$V \times 16$
0.216HZ	3.8	3.	1.8	1.5	0.6
0.248HZ	4.4	2.	1.6	1.2	0.8
0.302HZ	3.6	1.2	0.9	0.9	0.7
0.529HZ	2.	1	0.8	0.8	
0.648HZ	1.8	0.85	0.84		
0.745HZ	1.5	0.7	0.7		
0.918HZ	1.3	0.9			
1.188HZ	0.9				

V– recording Tape speed.