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PREDOMINANT VIBRATIONS OF THE SOUTH BISAN-SETO SUSPENSION BRIDGE

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1. INTRODUCTION: The South Bisan-seto Suspension Bridge, completed in 1988, is a three-span continuous suspension bridge with span length of 274 m + 1100 m + 274 m. South anchorage of the bridge stands by itself on the seabed, and the north anchorage is embedded slightly in the seabed.
Many microtremor measurements have been done on the south anchorage in 1985 and 1989 to investigate its natural frequencies [1,3]. The natural frequencies found in these studies showed a tendency to decrease over the period of 1985 - 1989. Moreover, there were some unidentified predominant vibrations found in the 1989 measurements. A new set of microtremor measurements was conducted in December 1994 to understand the dynamic behavior of the anchorage more clearly.
In this study, identification of the predominant vibrations of the anchorages was done through spectral analysis of the microtremor data and dynamic structural analysis of the bridge. The objectives were to investigate the unidentified predominant vibrations found in the previous measurements and to verify the mathematical model of the bridge used in the dynamic structural analysis.
2. MICROTREMOR MEASUREMENT: Extensive ambient vibration measurements were done on the south and the north anchorages from December 6 to 9, 1994. Microtremors that have very small amplitudes were measured by highly sensitive velocimeters (5.25 V/kine). The data were amplified 100 times and were filtered with 30 Hz low-pass filter before being recorded by a digital recorder with 16-bit A/D converter. The natural frequency of the velocimeters is 1.0 Hz. We did twenty-four recordings on the south anchorage and thirty-one recordings on the north one. Data were acquired with 200 Hz sampling frequency for 180 seconds in each recording. The sensors were set in three directions, those were longitudinal, transversal and vertical directions. Spectral analysis of the recording data was done to obtain the frequency contents of the data that will reveal the predominant vibrations of the anchorages.
3. MATHEMATICAL MODEL: The super-structure of the bridge was modeled as a 2-D linear finite element model. It had 163 elements and 118 nodal points, with 293 dof. The anchorages and piers of the bridge were modeled as rigid bodies with circular base lying on isotropic homogeneous elastic half-space. The equations of motion of a rigid body on elastic half-space were formulated by using the frequency-dependent dynamic compliance functions [2]. In the analysis, the super-structure and the foundations were treated as a single dynamic system. Since the equations of motion of the anchorages and piers are frequency-dependent, the analysis of the total system is best handled in frequency-domain [4].
4. RESULTS AND DISCUSSIONS: Figure 1 shows the spectral density functions of the microtremor vibrations of the south anchorage in longitudinal and transversal directions. Several predominant vibrations were detected here. The natural frequency of the sensors was 1.0 Hz in both longitudinal and transversal directions. The natural frequencies of the anchorage were 1.93 Hz and 1.68 Hz in longitudinal and transversal directions, respectively. The peak of 2.4 Hz in longitudinal direction was due to the natural vibration of the north anchorage transferred through the main cables of the bridge. These findings coincide with the computational results of the mathematical model shown in Figure 3. The shape of the base of the anchorage is a rectangle with four rounded corners. The model used in the analysis was a rigid body with circular base that has same area as the rectangle. It is expected that the calculated natural frequency of the model in horizontal mode (1.811 Hz) is between the natural frequencies of the actual anchorage in longitudinal and transversal directions. The small peak of 2.275 Hz was also observed in computational results as the influence of the vibration of the north anchorage.
Peak of 3 Hz (Figure 1) was due to the vibrations induced by passing trains during the measurements. Broad band peaks from 7 to 9 Hz found in the previous measurements (1989) were not detected in the present measurements.
Table 1 summarizes the natural frequencies of the anchorage obtained from the previous measurements and the present measurements. It shows no significant change between the natural frequencies obtained in the present measurements and the 1989 measurements. On the other hand, it shows quite significant decrease in the natural frequencies over the period of 1985 - 1989. One possible explanation is that the elasticity of the supporting ground decreased over this period.
The natural frequencies of the north anchorage obtained from the microtremor data analysis were 2.401 Hz in longitudinal direction and 2.303 Hz in transversal direction (Figure 2). The computational result of its dynamic model showed that the natural frequency of it in horizontal mode was 2.275 Hz (Figure 4). This value is smaller than the value obtained from microtremor measurement in accordance with the reality that the anchorage is slightly embedded in the ground, not just stands freely on it as used in the computational model.

5. CONCLUSIONS : In the present study, we found no significant decrease in natural frequencies of the south anchorage. This finding suggests that the continuous decrease in its natural frequency did not occur. The microtremor measurement is a good tool to identify the predominant vibrations of massive structures, like anchorages of long-span suspension bridges, where forced vibration test is not feasible. The field investigation is also served as a good verification tool for the mathematical model used in the dynamic analysis of soil-structure interaction. The natural frequencies obtained from the spectral analysis of the microtremor data and the computational results showed good agreement.

6. REFERENCES :

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Table 1 Comparison of the natural frequencies of the south anchorage

Year of measurement	1985	1989	1994
Longitudinal (Hz)	2.08 ± 0.06	1.94 ± 0.03	1.93 ± 0.02
Transversal (Hz)	1.76 ± 0.04	1.69 ± 0.02	1.68 ± 0.03

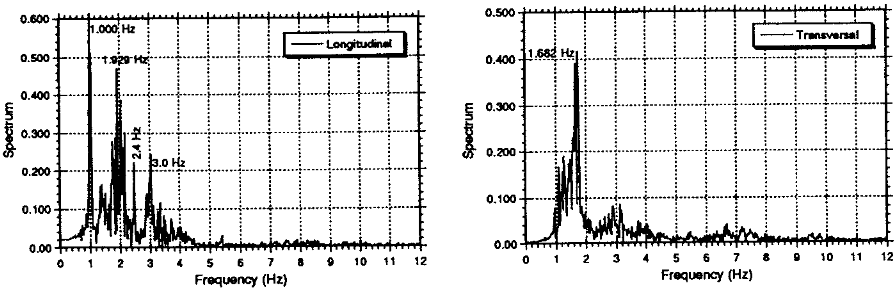

Fig. 1 Spectral density function of the microtremor vibration of the south anchorage

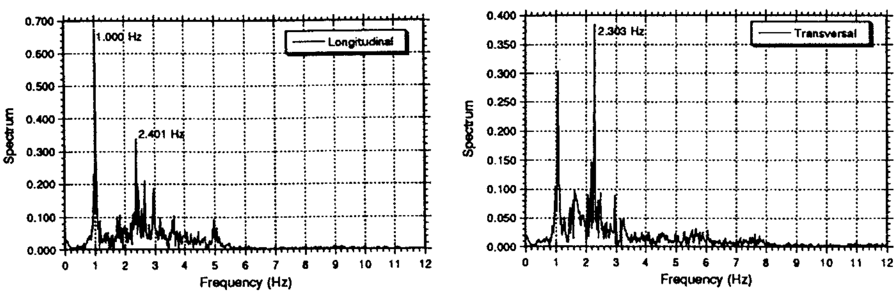

Fig. 2 Spectral density function of the microtremor vibration of the north anchorage

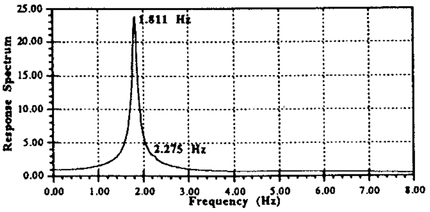

Fig. 3 Longitudinal response of the south anchorage

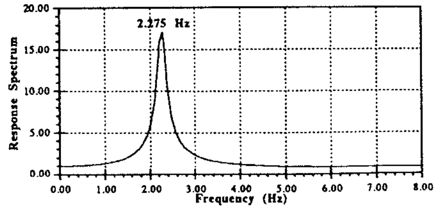

Fig. 4 Longitudinal response of the north anchorage