Vibration Test on Existing Steel Sheet Pile

Sakhiah Abdul Kudus¹, Kunitomo Sugiura², Yasuo Suzuki³

¹ Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.
² Department of Civil and Earth Resources Engineering, Graduate School of Engineering, Kyoto University, Kyoto, 615-8540, Japan.
³ Department of Civil Engineering, Faculty of Sustainable Design, University of Toyama, Toyama, 930-8555, Japan
Corresponding author: sakhiah@uitm.edu.my

Abstract. A thorough understanding about the vibration of a structure is essential to resolve any vibration problems. In this study, the vibration measurement was conducted on a real plate structure, which is steel sheet pile. The monitored structures are located in Rokkenya-gawa river and Aji-gawa river in Osaka City, Japan. The purpose of this investigation is to obtain information about the overview conditions of this marine structure. A simple vibration measurement as well as thickness measurement have been conducted. There is no serious damage was observed on the monitored structure.

1. Introduction
The vibration characteristics needs to be understood first before any meaningful use in the field of structural health monitoring. The applications of modal testing is a form of experimental evolution conducted to determine the dynamic properties of a structure. In recent years, efforts have been made to combine the modal testing with the analytical methods. Modal testing deals with a real structure directly, and utilizes the analytical method to verify both methods. There are several methods applicable for excitation of the structure and normally are pure random, burst random, period swept sine and hammer impact. The use of hammer impact has a poor signal to noise ratio [1]. The dynamic characteristics of the shaker may be combined with the test structure when the shaker is used to conduct modal testing. Use of the dynamic properties of structure such as natural frequency and mode shape to evaluate the damage has extensively been studied [2-5].

Vandepitte and Olbrechts [6] studied the dynamic behaviour of the test structure when the structure was excited by different excitation methods [6]. Three methods of excitation were considered: hammer excitation; shaker with stringer excitation; and internal shaker excitation. The results obtained show that the loading methods do influence the results obtained. Thus, the loading effect is one of the important parameter to be considered. The study also concludes that the inertial shaker does not only add mass to the system, but may also increase the stiffness of the complete system.

In vibration analysis, free vibration is the natural response of a structure due to impact or displacement. The responses obtain are based on properties of the structure and the vibration data acquired from examination of the mechanical properties of the monitored structure. Structural vibration is generally measured by an electronic sensor which converts the vibration motion into the electrical signal. By analysing the signal, the nature of the vibration can be obtained. The dynamic measurements
are normally conducted using an accelerometer, where the measurement of vibration response is conducted by mounting the accelerometer to the surface of the structure. The damage assessment based on vibration technique was selected mainly due to merit of this technique which have the ability to inspect large region in short time, low implementation cost, relatively sensitive towards the local changes in the structure, low energy consumption and repeatability. This study aimed to investigate the vibration characteristic of existing sheet pile exposed to marine environment using vibration test.

2. Methodology
The use of corrugated plate for retaining walls and embankments has received worldwide acceptance due to high strength, lower cost and ease of installation. Figure 1 shows the schematic diagram of the steel sheet pile embedded in soil backfill. Normally, a steel tie rod is used to tie back the sheet pile. The tie rod system is categorised as the most economical sheet piling tie back. The front side of steel sheet pile was facing to the water river side while another side of steel sheet pile is facing to the backfield, which indicates that the backside of this structure is inaccessible for any maintenance or inspection work. The assessment of this type of structure is challenging because of limited access to the structure. The steel sheet pile is only accessible on the river side, and the other side of sheet pile was embedded in the backfill.

Figure 1. Schematic diagram of steel sheet pile embedded on backfill.

Figure 2 summarizes the testing procedure for modal testing. Normally, the data from modal testing is further analysed for estimation of frequency response function (FRF) to obtain other modal parameters like mode shape and modal damping. A physical structure has an infinite number of mode shape together with resonance frequencies. However, in this work, mode shape and modal damping were not possible to be obtained from the vibration test conducted on steel sheet pile because of limited vibration measurement. In order to obtain the mode shape and modal parameters of the monitored structure, large number of discrete measurement response points need to be recorded on the surface of the structure. In addition, improper selection of a discrete point where the measurement is conducted on nodal points leads to inaccurate characterization of mode shape. The FRF is describe as the relationship between two points in the input-output as a function of frequency.

Figure 2. Basic vibration measurement for modal testing.
3. Results and discussion
The vibration measurement was conducted on a real plate structure, which is steel sheet pile. The purpose of this investigation is to obtain information about the overview conditions of this marine structure. A simple vibration measurement as well as thickness measurement has been conducted. Figure 3 depicts the site on the Aji-gawa river. The site visit was done on February 2016. The steel sheet pile was used as permanent support. The thickness measurement was conducted on several points and the losses of thickness is about 0.4 mm. The intact thickness of this wall is 10 mm. Thus, it can be concluded that no serious corrosion damage happened here from the thickness measurement data table 1 and table 2 show details of the structure age and maintenance schedule on steel sheet pile located at Aji-gawa river and Rokkenya-gawa river respectively. The structure is almost 50 years old but no serious damage was observed. This was related to the properly scheduled maintenance provided by the authorized authority.

![Figure 3. The preliminary investigation of health condition of steel sheet pile located at Aji-gawa river, Osaka.](image)

| Table 1. Construction and maintenance details of Aji-gawa river sluice water. |
|-----------------------------------------------|
| Year of construction | 1970 (March) |
| Age of structure (during the inspection) | 46 years |
| Type of plated structure | Steel sheet pile |
| History of coating and/or painting | 1998 and 2013 |
| Galvanic protection | 2018 (plan) |
| Others | - |
Table 2. Construction and maintenance details of Rokkenya-gawa river flood gate J1.

|                              |                |
|------------------------------|----------------|
| Year of construction         | 1969 (March)   |
| Age of structure (during the inspection) | 47 years       |
| Type of plated structure     | Steel sheet pile |
| History of coating and/or painting | 2013           |
| Galvanic protection          | 2013           |
| Others                       | -              |

The vibration test was conducted using an impact hammer, vibration shaker and accelerometer. An accelerometer is a simple mechanical device used in the engineering field to measure the acceleration force. The force in this work is induced via vibration shaker and impact hammer. Figure 4 details the location of excitation and the position of the accelerometer. Two accelerometers were placed in a fixed position 1 m apart and excitation was made in the middle between the both of accelerometer. The frequency of excitation varies from 50 Hz up to 400 Hz using the vibration shaker. Signal analysis can be divided into time and frequency domain, and each domain provides a different view and insight into the vibration.

Fast Fourier transform (FFT) is used to convert an original signal normally in the time domain to representation in the frequency domain. Figure 5, Figure 6, and Figure 7 represent the frequency domain data of the sheet pile when excited by the vibration shaker with frequencies of excitation of 50 Hz, 100 Hz and 150 Hz respectively. The analysis involves imposing excitation on the plate structure and determining the frequency at which the structure resonates when the excitation and the vibration response match. The data was captured by the accelerometer from Channel 1 located at the bottom part of the sheet pile. From the results obtained, the peak of 66.47 Hz might represent one of the resonance frequencies of this structure. In addition, the modal testing result for pile excited by the impact hammer was presented in Figure 8. The pile was excited by several impacts. This section summarize how the impact wave was generated and the vibration response obtained. In order to understand the vibration of the structure, the steady vibration is necessary as compare to only one or small number of impacts. The steady vibration can be induced from the actuator and vibrator.

![Figure 4](image-url)  
**Figure 4.** The details of excitation and measurement point on steel sheet pile structure located at Rokkenya-gawa.
**Figure 5.** The FFT result from accelerometer Channel 1 when the pile was excited with frequency of 50Hz by shaker.

**Figure 6.** The FFT results from accelerometer Channel 1 when the pile was excited with frequency 100Hz by shaker.
4. Concluding Remark
The appropriate usage of vibration testing in instrumentation and analysis benefits understanding of problems in the structure. The important information related to structural characteristics including modal parameter can be further obtained. Preliminary vibration tests have proven to be useful in the optimization of methodology and equipment to be used for detailed investigation. Moreover, vibration measurements give advantages to forecasting the extent of damage in a structure from modal parameters obtained during analysis.
5. References

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