A CASE STUDY ON THE EVALUATION OF STRUCTURAL CONDITIONS FOR AN EXISTING BRIDGE USING POSITION SENSITIVE DETECTOR (PSD) DEVICE

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ABSTRACT

A study for the evaluation of the structural conditions for an existing bridge using position sensitive detector (PSD) technology is presented in this paper. Comparing to other traditional methods, which commonly requires direct contact to the structure with a complex wire deployment, however; non-contact real-time displacement measurement is the best method to assess the structural integrity where other physical characteristics such as velocity and acceleration can be easily derived without deviation. To achieve the above mentioned purpose, the new developed PSD device is applied in this case study.

The PSD based displacement measuring system is composed of two parts: the LED targets which emit the spot lights and the PSD V-Cam which captures the spot lights. To verify the performance and reliability of the PSD device, a series of impact test were conducted onto a bridge structure. Moreover, nonlinear dynamic response analysis was performed based on a fine-tuned finite element model. Comparison on both time history and frequency domain analysis has demonstrated that the measured data and the analysis result fit well each other.

INTRODUCTION

Up to present day, most of the bridge health checks are focused on the structure members and performed with visual inspection. However the conventional health check is unable to offer sufficient information on the integrity of entire structure. To assess the structural integrity, real time high precision deformation measurement is the best method. Based on measured deformation data, valuable information such as the maximum deformations, the vibration characteristics, the fundamental frequency and the attenuation ratio of the bridge structure can be acquired.

This case study was performed in Taiya Bridge's piers in Taiwan which is supported on caisson foundations (Figure 1). The river bed level was getting lower year by year resulting in the scouring of foundations. Thus, most of the caisson foundations were seriously exposed and there was a concern about their lateral bearing capacities. In 2009, retrofitting work has been officially determined. To check the effect of retrofitting work, the measurement of its dynamic response before and after the retrofitting work was performed. In this paper, only the data collected before the retrofitting is discussed. In this study, a newly developed PSD device based on non-contact real-time deformation measurements was used. This device is composed of two parts: the LED targets which emit the spot lights, and the PSD V-Cam which captures the LED targets' spot lights. A single target was mounted onto the side face of the pier's cap beam. A 60 kg timber log (Figures 2 and 3) was employed for the impact. PSD V-Cam was set directly on the ground level outside the caisson foundation. After the data acquisition, FFT analysis was used to acquire the fundamental frequencies. Finally nonlinear dynamic response analysis was performed to simulate the pier's dynamic behavior.

Figure 1. Taiya Bridge View

Figure 2. Impact Test

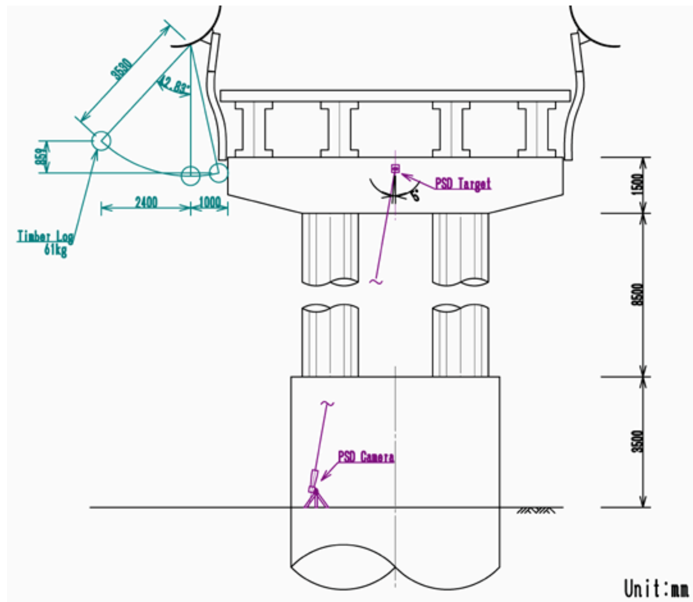

Figure 3. Impact Test Configuration (Pier 31)

IMPACT TEST RESULTS

The real time lateral and longitudinal deformation curves at the top of the tested pier 31 (P31) cap beam subjected to consecutive six impact loads are shown in Figure 4.

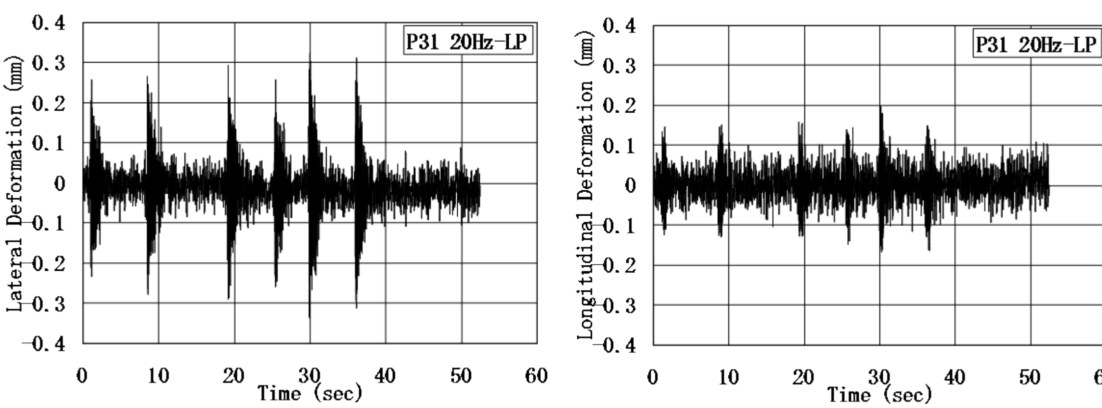

Figure 4. Real Time Deformations at Top of Cap Beam (P31)

The lateral and longitudinal deformation curves caused by the last impact are enlarged and shown in Figure 5. Some observations from this figure are:

1. The maximum lateral deformation is 0.31mm.

2. It takes 1.7sec for the lateral deformation to attenuate to the original status.
3. The lateral attenuation ratio is approx. 0.01.
4. The fundamental frequency in lateral direction is approx. 16Hz.
5. The maximum longitudinal deformation is 0.15mm.

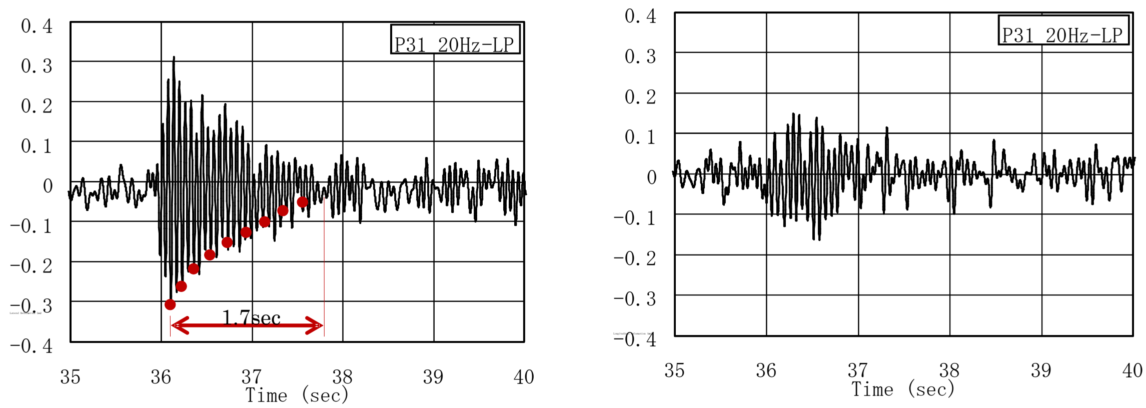

Figure 5. Real Time Deformation at Top of Cap Beam (P31) for the last impact record

The FFT analysis result of P31 is shown in Figure 5. Apparently P31 has a fundamental frequency of 15.7Hz. This frequency is the same as that acquired from the measured deformation curve. This fundamental frequency can also be acquired during the daily traffics loading without applying any impact force. It was considered that this frequency is high enough to assume that this pier is structurally sound. For example, similar analysis for piers 26, 27, 28 revealed low frequencies of 3.5, 0.9 and 0.9 Hz, respectively. These low frequencies may indicate some structural deficiencies in these piers which were actually retrofitted.

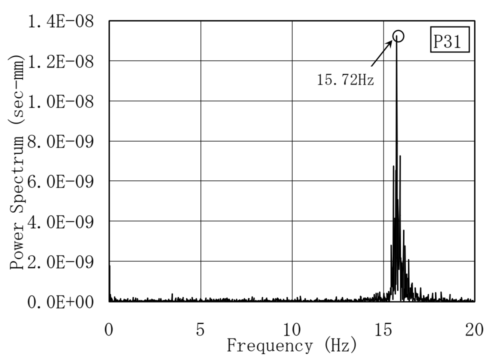

Figure 5. Fundamental Frequency of P31

SIMULATION ANALYSIS

To simulate the pier's dynamic behaviours, Finite Element Method (FEM) Program Midas is employed to perform the nonlinear dynamic response analysis. The pier is modelled by 3 dimension solid element as shown in Figure 6. Material's nonlinear property is considered in the simulation analysis. Input external impact force is shown in Figure 7.

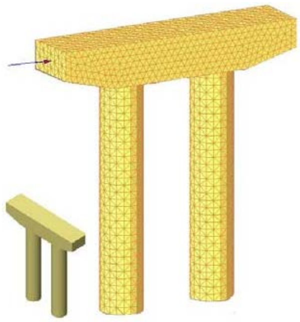

Figure 6. Simulation Model

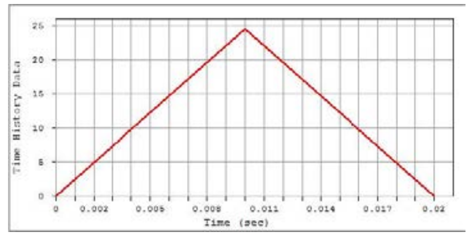

Figure 7. Input Impact force

The first and the second impact test results are simulated. The simulation results are shown in Figure 8. Both figures show that the deformations reach the maximum value soon after the application of the impact force, and then attenuate gradually to their original status. Both cases show that the attenuation rate is very slow and the attenuation ratio is approximate 0.01. The significant difference in the amplitudes of the first wave may be caused by the inefficiency of the real impact. However, the rest of the measured values well agree with the computed values.

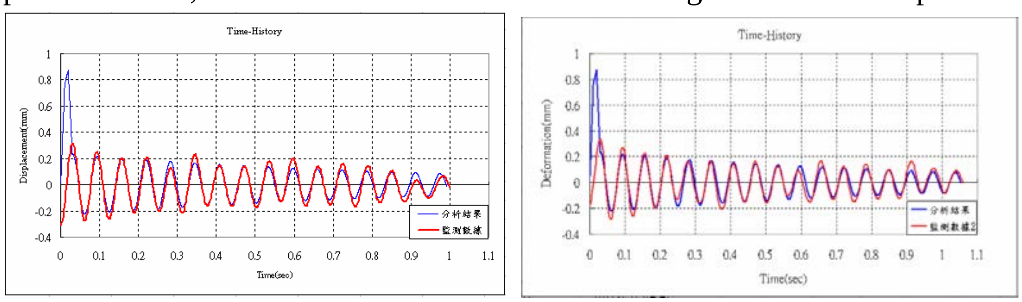

Figure 8. Deformation time histories of P31

CONCLUSIONS

In this paper, a newly developed PSD method based on dynamic behaviour measuring device and a practical application of this device on a bridge pier health check are introduced.

Through this application, followings are concluded.

1. PSD device possesses the capability to precisely measure the dynamic behaviours of bridge pier structures, and to assess their characteristics of deformation, vibration, and attenuation.
2. Comparisons on both deformation time history and fundamental frequency have demonstrated that the measured data and the analysis result fit well each other. The applicability and effectiveness of this measuring method particularly on the bridge substructures to check up their integrity are verified through this study.

REFERENCES

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