Fundamental Study on Health Monitoring and Evaluation System for Port/Airport Facilities

by

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ABSTRACT

Port facilities, coastal facilities and man-maid island airport facilities exhibit superior performances in marine environments, however they are difficult to be maintained in good conditions while exposing to severe atmosphere. Therefore, it is important to establish a comprehensive health monitoring and evaluation system for satisfying required performances such as quick quantitative input to assess and decide on post-earthquake action. As a part of the system, this paper focuses on sensing devices to observe a steel pipe pile condition during an earthquake.

KEYWORDS: Airport Facilities, Health Monitoring, Pile, Port facilities, Post Earthquake Action, Seismic Retrofit.

1. INTRODUCTION

The occurrence of a large earthquake near a major city may be a rare event, but its societal and economic impact can be so devastating that it is a matter of national interest. Lessons learned from the 1995 Kobe earthquake disaster, from the point of view of the social port function, this experience showed us the following two important concepts for port administration and management. Those are;
a) Starting special operation for transporting living necessities for victims' daily life immediately (within one day) after an earthquake. b) Restarting commercial logistic operation within one week after an earthquake. It is difficult to evaluate level of damage to the facilities quickly, because of major parts of facilities are located under-ground and submerged. It is also difficult to calculate stability of complex structures due to retrofit or upgrade construction work compared with simple structures.
To establish a health monitoring system, we conducted a series of fundamental experiments. In this paper, we introduce an application of optical fiber sensing technique and real time dynamic global positioning system (RTD-GPS) technique for steel pipe pile.

2. FIELD EXPERIMENTS

In case of Tokyo bay, steel pipe piles for foundation of bridge and pile supported wharf are driven into 50m-100m depth with one or two welded connections. And the design service time is 100 years.

2.1 Optical fiber sensor for steel pipe pile

To assess the applicability and reliability of optical fiber sensing system for detecting strain level of pile during construction process and during life span (100 years) of the pile, a series of full-scale experiment was conducted. As shown in Fig. 1, two pieces of 0.6m diameter, 8m long steel piles were provided and attached three types of strain sensors (i.e. FBG optical fiber, BOTDR optical fiber and conventional strain gauge). From the soil profile (Standard penetration test N value shown in red) near the driving position, we selected vibrohammer for pile driving. However, the soil profile (blue line) converted by CPT at the certain position shows more sever condition for pile driveing. Fig. 2 show that the attached sensors with protection. Figs. 3 and 4 show the driving process and special treatment at the welding position. After driving the pile, vertical load was applied using a hydraulic actuator as shown in Fig. 5
Fig. 6 show the strain distribution with depth at five loading stages. The blue line and red line indicate that the strain distribution by BOTDR

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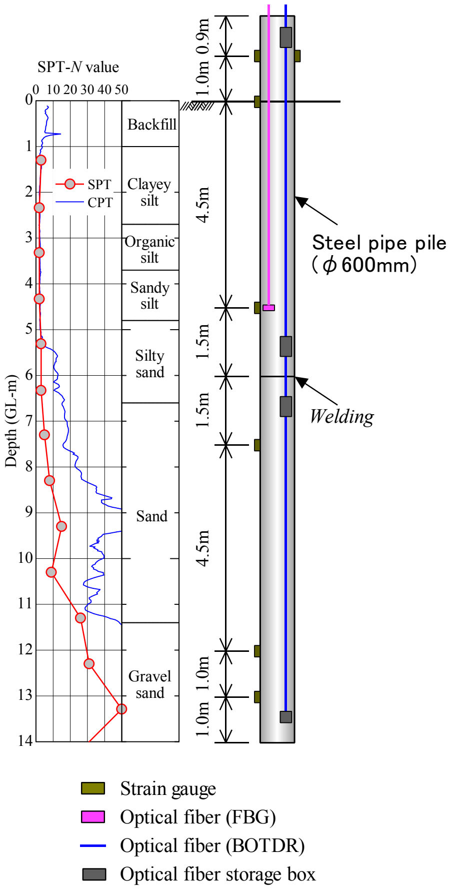

Fig. 1 Test site condition and pile

Fig.2 Test specimen pile and attached sensors

Fig.3 driving the pile with vibrohammer (Top piece of pile)

Fig.4 Welded connection between bottom and top pieces of pile and treating optical fiber

Fig.5 Setup of loading hydraulic actuator

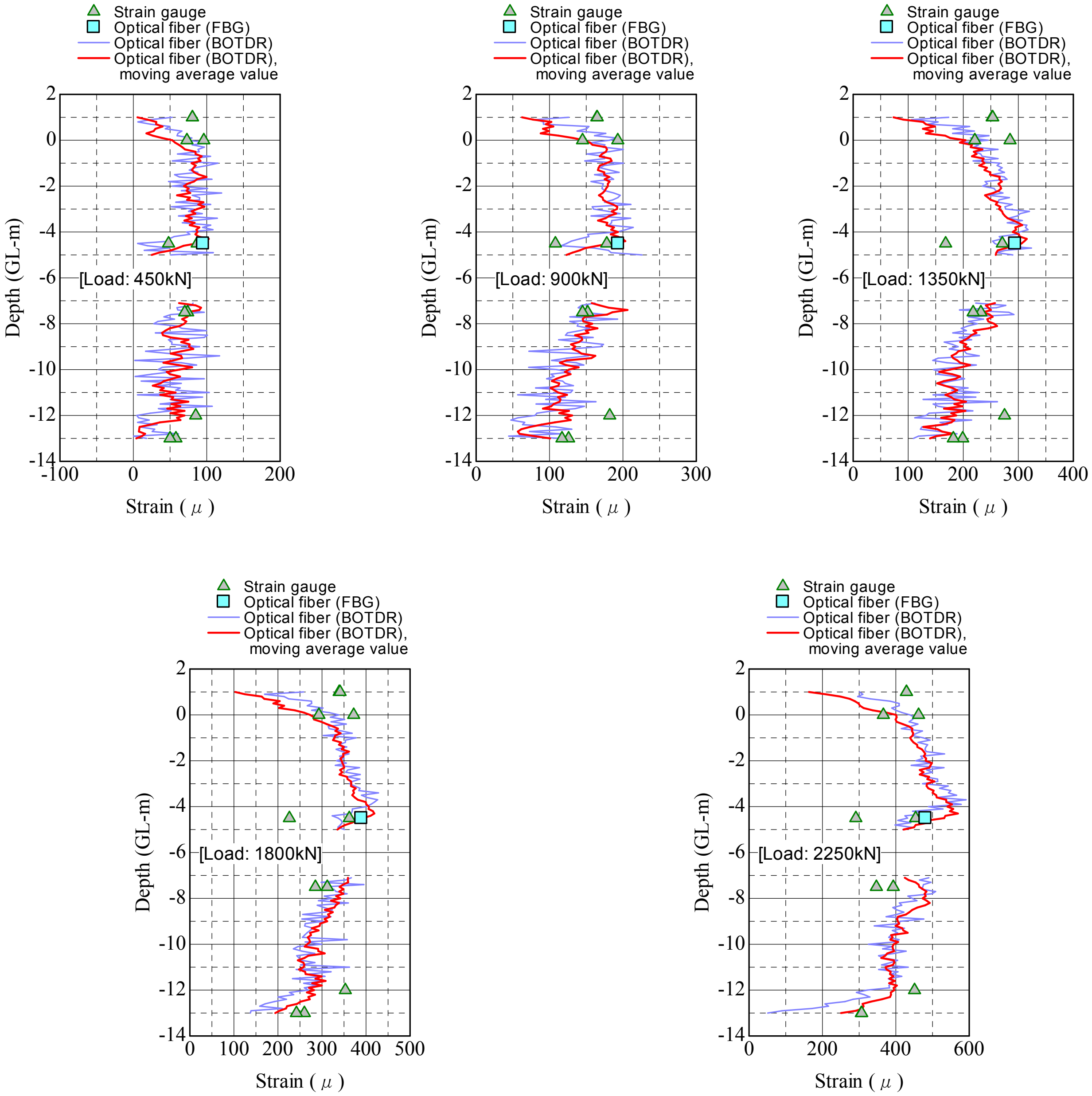

Fig.6 Strain distributions obtained by FBG, BOTDR and conventional strain gauges during loading stage.

in diagonal positions of pile cross section. The ideal neutral axis of pile is not coinciding with the actual neutral axis of the pile, and that is why probably the red and blue line are scattering. The FBG optical fiber (blue squares) and the conventional strain gauge (gray triangle) are also plotted in these figures.

From the practical point of view, the four sensing technique results show good agreement and survived during driving vibration and impact force.

We also, tried full-scale tests are ongoing as follows,

a) Tokyo-bay: 1.5m diameter, 60m length pile, steam hammer.

b) Osaka-bay: 1.2m diameter, 50m length pile, vibrohammer.

c) Exposure tests: Sensor devices expositing in seawater submerged zone, tidal level change zone and splash zone.

Left: Reference (fixed) receiver point Right: Shaking receiver point

Fig. 7 RTD-GPS test field located in Nobi, Yokosuka

2.2 Real Time Dynamics-GPS

To calculate the stress condition or bending moment distribution of the pile from the strain distribution data, we assume that the boundary condition of pile at the bottom end is fixed and the top end displacement is given. To measure the top end displacement during construction stage, during an earthquake, and after an earthquake, the RTD-GPS technique was tested. Fig. 7 shows the field test setup. During damage and failure process of a pile supported wharf, the stress condition of pile is important index to evaluate the damage level, and, it is not only residual stress condition but also maximum stress condition during an earthquake. The GPS receiver is put on a portable shaking table as shown in Fig.9.

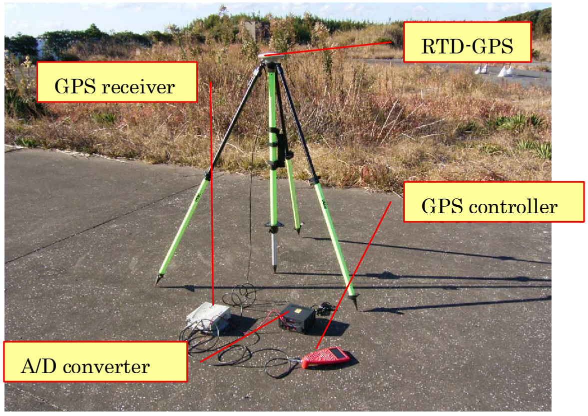

Fig. 8 RTD-GPS Reference receiver

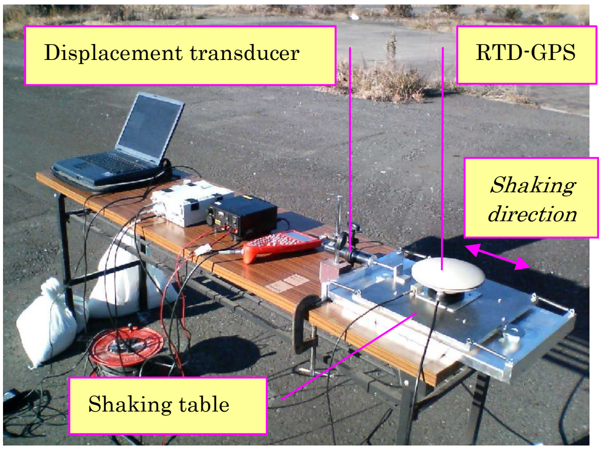

Fig. 9 RTD-GPS Moving receiver

To evaluate the dynamic property of the RTD-GPS, we compare the displacement time histories obtained by the conventional LVDT transducer and RTD-GPS with different input frequency. In the field test, sampling frequency of 100Hz in conventional LVDT, and 10Hz in RTD-GPS are used.

In Fig. 10, the displacement obtained by a conventional LVDT as shown in solid blue line and RTD-GPS data points indicate good agreement during 0.8Hz shaking. On the other hand, in case of 2.5Hz shaking condition, the RTD-GPS data points show large displacements as shown in Fig.11. Before the field test, we assumed that the sampling frequency and shaking frequency ratio leads ‘under sampling’ effect in case of 2.5Hz shaking.

At this stage, we can not verify it and come to a conclusion yet. Next tests are ongoing to evaluate the applicability of random shaking using strong motion records.

3. CONCLUDING REMARKS

We are just started fundamental study on a health monitoring related issues such as sensor technology, information technology, environmental impact analysis and material deterioration database etc.

The final goal is establish integrated health monitoring systems which enable real-time monitoring, automatic damage detection, assist crisis management and assist lifecycle management. Damage identification is performed based on identification of changes in salient response features of the structure, as measured by deployed sensor arrays. This proposed broad interdisciplinary research aims to develop a next-generation, versatile, efficient, and practical health monitoring strategy.

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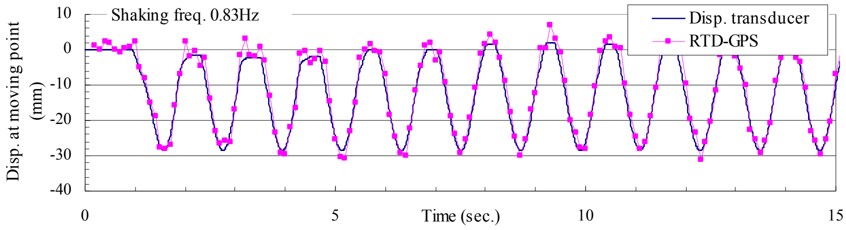

Fig. 10 Time history of horizontal displacement (shaking frequency 0.8Hz)

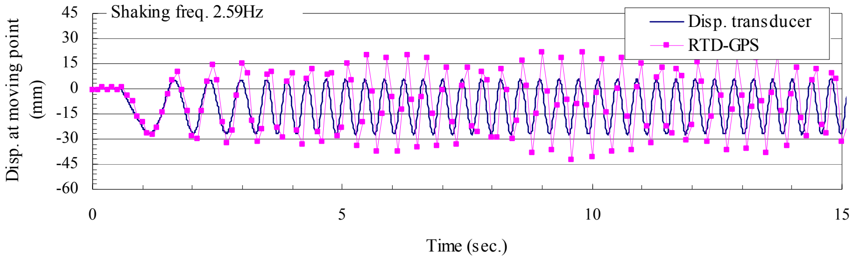

Fig. 11 Time history of horizontal displacement (shaking frequency 2.5Hz)