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Static and dynamic pile testing of reinforced concrete pileswith structure integrated fibre optic strain sensors

Static and dynamic pile testing of reinforced concrete piles with structure integrated fibre optic strain sensors

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ABSTRACT

Static and dynamic pile tests are carried out to determine the load bearing capacity and the quality of reinforced concrete piles. As part of a round robin test to evaluate dynamic load tests, structure integrated fibre optic strain sensors were used to receive more detailed information about the strains along the pile length compared to conventional measurements at the pile head. This paper shows the instrumentation of the pile with extrinsic Fabry-Perot interferometers sensors and fibre Bragg gratings sensors together with the results of the conducted static load test as well as the dynamic load tests and pile integrity tests.

Keywords: static load test, dynamic load test, pile integrity test, extrinsic Fabry-Perot interferometer, fibre Bragg grating, structure integrated sensor, fibre optic strain sensor

1. INTRODUCTION

Reinforced concrete piles are typically used when structures are constructed on soft ground. Their purpose is to transfer the load of the structure into a deeper soil layer with an adequate load bearing capacity. In order to determine the load bearing capacity and the quality of the pile, usually either a static load test or a dynamic load test is carried out. Because of cost- and time-efficiency, dynamic load tests are becoming more popular than static load tests. But at the same time, there are still some doubts concerning the reliability of dynamic load tests. Within the scope of evaluating the results from several dynamic load tests, BAW and BAM organised a round robin test with five well-known providers of dynamic pile tests from Germany. For this test, eight cast-in-place bored piles have been built at the BAM Test Site Technical Safety in Horstwalde, south of Berlin. Six piles were used for dynamic tests while the remaining two piles were used for static and dynamic tests. In order to receive more detailed results about the strains along the pile length during the pile tests, fibre optic strain sensors have been integrated into one pile. This paper shows the instrumentation of this bored pile with the structure integrated fibre optic strain sensors and the results of the static and dynamic pile tests. The results of the round robin test itself have already been published by Herten et al.[1].

2. SENSOR SETUP OF THE CAST-IN-PLACE BORED CONCRETE PILE

From the eight bored piles, pile number one was equipped with two different types of fibre optic strain sensors. The left side of figure 1 shows the first sensor type, which is an extrinsic Fabry-Perot interferometer (EFPI) sensor. This sensor was developed at BAM and more detailed information about the sensing principle has been published by Schilder et al.[2]. The second sensor type is a commercially available fibre Bragg grating (FBG) sensor which can be seen on the right side of figure 1. This sensor consists of a FBG for strain measurements and an additional FBG for temperature compensation. All sensors have been calibrated at the laboratory before their use.

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Figure 1: EFPI sensor (left) and FBG sensor (right).

The pile is equipped with three measurement levels at -1.5 m, -5.5 m and -9.25 m seen from the pile head. Each measurement level consists of two EFPI sensors and one FBG sensor. The sensors have been welded at the reinforcement cage with an angular offset of 120°. Additionally, the pile is equipped with a load bearing cell at the pile toe. The setup of measurement level three with the load bearing cell is shown on the left side of Figure 2 while the orientation of the sensors is shown on the right side.

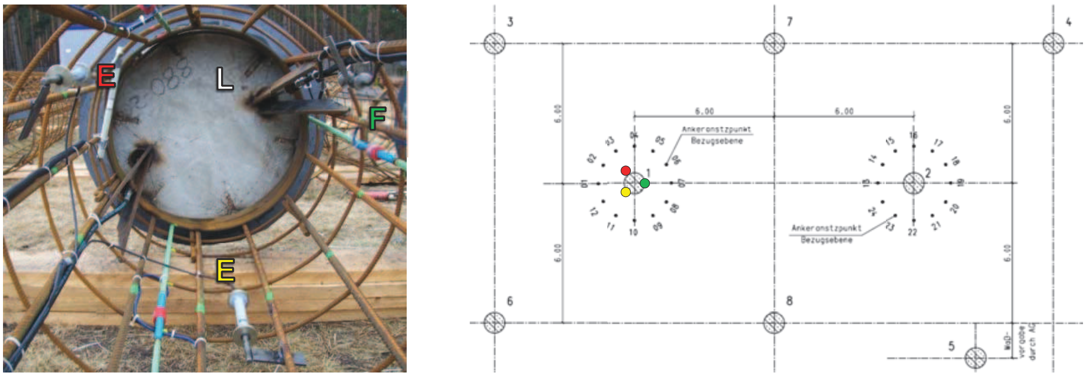

Figure 2: left: Sensor setup of two EFPI sensors (E), one FBG sensor (F) and the load bearing cell (L), right: orientation of the sensors.

3. CONDUCTED PILE TESTS

Pile one was used for the static load test as well as the dynamic load tests and pile integrity tests. The setup for the static load test with the anchors and the loading platform can be seen in Figure 3, left. The right side of Figure 3 shows the setup for the dynamic load test with the crane and the drop weight.

Figure 3: Static load test (left) and dynamic load test (right)

3.1 Static load test

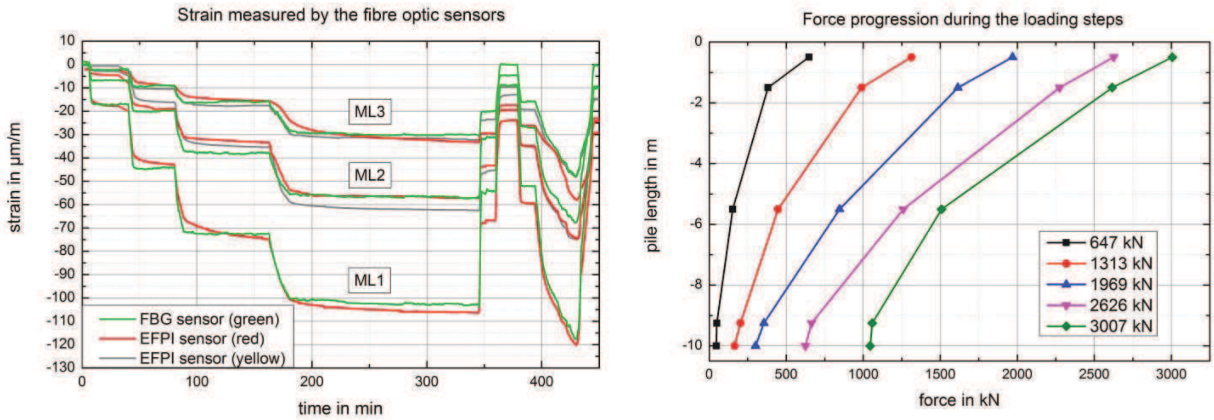

Figure 4: Strain measured by the fibre optic sensors (left) and force progression during the loading steps (right).

First, the pile was loaded stepwise with 25 %, 50 %, 75 % and 100 % of the calculated working load (2625 kN). The end of each loading step was determined by the creeping criterion. After stepwise unloading, the load was increased up to the working load again, but the creeping criterion could not be matched anymore. Therefore, a jump test was carried out to gain additional information about the pile's behaviour. Figure 4 shows the strain measured by the fibre optic strain sensors on the left side and the force progression during the loading steps on the right side. The top and bottom values of the force progression are derived from the load bearing cells at the pile head and the pile toe. The remaining values are calculated from the measured strains. Shaft friction can be determined as the major component of the load bearing capacity of the pile.

3.2 Dynamic load test and pile integrity test

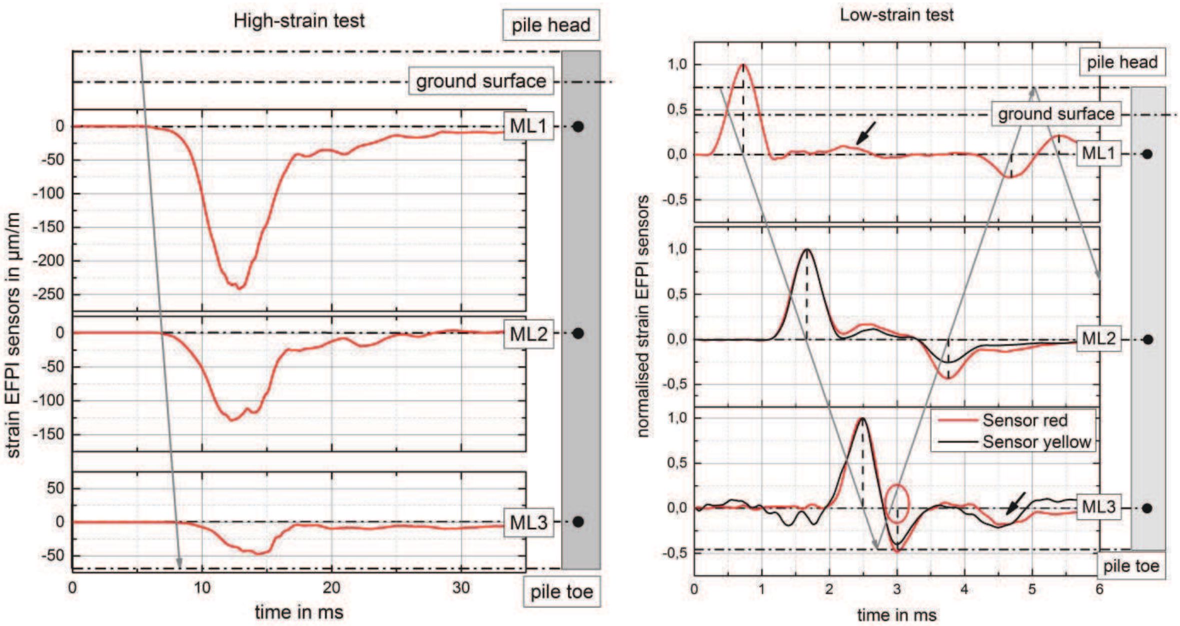

Figure 5: Dynamic load test with 11 t drop weight and 0.75 m height (left) and pile integrity test (right).

The dynamic load test has been measured with FBG and EFPI sensors, but because of the critical sampling rate of the optic interrogator (1 kHz) for the FBG sensors, the measured strain signal could not be considered for the analysis. Figure 5, left shows the strain distribution at the measurement levels detected by the EFPI sensors at a drop height of 0.75 m. The sensors could clearly detect the strain caused by the impact of the drop weight until the last drop height of 1.32 m. Figure 5, right shows the normalised strain measured by the EFPI sensors during the pile integrity test. The absolute strain values could not be calculated anymore because of the signal attenuation along the pile length caused by shaft friction. It can be seen that the forward and reflected strain waves are detected clearly. Because of the short distance from measurement level three to the pile toe, both strain waves overlap and the detected peak of the reflected wave differs from the theoretic peak, which is encircled in red in Figure 5. It was observed that piles which were only tested dynamically were severely damaged approximately 4 m below the pile head. This damage was caused by the high strain of the reflected wave which exceeded the elasticity of the pile. Pile one and two did not receive damages in a similar extend because of the activation of the tip resistance during the previous static loading. The slight change in impedance pointed out with an arrow in Figure 5 might be caused by such a crack, since it could not be observed before the dynamic load test. Measurement level two cannot pick the change in impedance up because it is too close to the possible crack.

4. CONCLUSIONS

Structure integrated fibre optic strain sensors have been successfully used for the static load test as well as dynamic load tests and pile integrity tests. The EFPI sensors were able to detect and measure the applied loads during all conducted pile tests. The FBG sensors showed a promising performance as well, but their suitability for dynamic measurements could not be confirmed yet due to lack of a measurement device with a suitable sampling rate and resolution. The next step concerning the data analysis will be the comparison of the results measured with the fibre optic strain sensors with the results of the conventional pile testing methods, as published by Schallert[3] and Schallert et al.[4]. Since the piles are accessible at our testing facility, further investigations such as the damage detection of possible cracks might be conducted.

ACKNOWLEDGMENTS

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