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Research on the layout of optical fibers applied for determining the integrity of cast-in-situ piles

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ABSTRACT

Distributed optical fiber temperature sensing technology has the potential to be used to determine the cast-in-situ pile integrity. This study proposed an arrangement of optical fibers for obtaining the pile integrity in situ, and it provided a calculation model for the temperature distribution. A model pile was constructed with the dimensions of 1.5 m × 0.5 m × 0.5 m. The fibers were implanted parallel to the center axis of the pile with a spacing of 0.04 m. The heat conduction area generated because of the heating of the fiber in the center of the pile was tested. The test results indicated that the heating conduction area was limited for certain heating powers. Furthermore, for the heating conduction area and heating power, care must be taken while arranging the optical fibers in the piles to determine the integrity.

1. Introduction

Cast-in-situ piles buried underground are widely used in civil engineering. The presence of pile defects is inevitable because of construction and the complex geological environment, which affect the bearing capacity of the pile [1]. The quality assurance of cast-in-situ piles depends on the installation monitoring as well as post construction integrity testing, among which the latter is subject to the interpretation of the testing engineer.

Integrity test methods most commonly use the pulse echo test and variations of sonic hole testing, each having its own advantages and disadvantages [2–4]. However, a relatively new testing technique called thermal integrity profiling (TIP) is becoming a more utilized alternative [4–6]. For TIP, temperature measurements are recorded during the hydration of cement and are post-processed to yield the overall pile integrity. Bulges, necks, cage alignment issues, and poor-quality concrete may be interpreted from the post-processing results to provide a better understanding of any integrity issues of the pile. TIP is different from other integrity methods available because the test is performed during, as opposed to after, the curing process.

Distributed optical fiber temperature sensing technology (DTS), which measures the temperature distribution along an optical fiber, was proposed for pile integrity detection [7,8]. This method also belongs to the category of TIP. In addition to the specification of tests during the concrete curing period, a major advantage of DTS is that it can obtain the temperature field of the pile in a short span of time when an optical fiber is appropriately implanted in the pile. If there are defects in the piles, then the features of the pile materials are non-uniform and the coefficient of thermal conductivity of the pile body is anisotropic. Research has shown that DTS can be applied for identifying the defects in piles by sensing the temperature from the hydration of cement or by heating the fiber and analyzing the temperature distribution differences caused by the defects. Studies have established from model tests the quantitative relation between the heat transfer coefficient and pile defects.

However, the application of DTS in pile defection tests is still in the research stage. Thus, some key questions need to be answered for its propagation and application [9]. For a pile, the number of fiber optic sensors that need to be attached and a method for a quantitative determination of the type of defects, which affect the DTS application in the detection of the defects in piles, must be obtained.

The current study proposes a theory design method for the fiber sensor layout in a pile. The next section of the paper presents a model test for the fiber layout and heating. The results from the theoretical derivation and experiments are given and discussed. Finally, the key conclusions are drawn.

2. Detection principle

For a cast-in-situ concrete pile, the fibers are embedded in the pile

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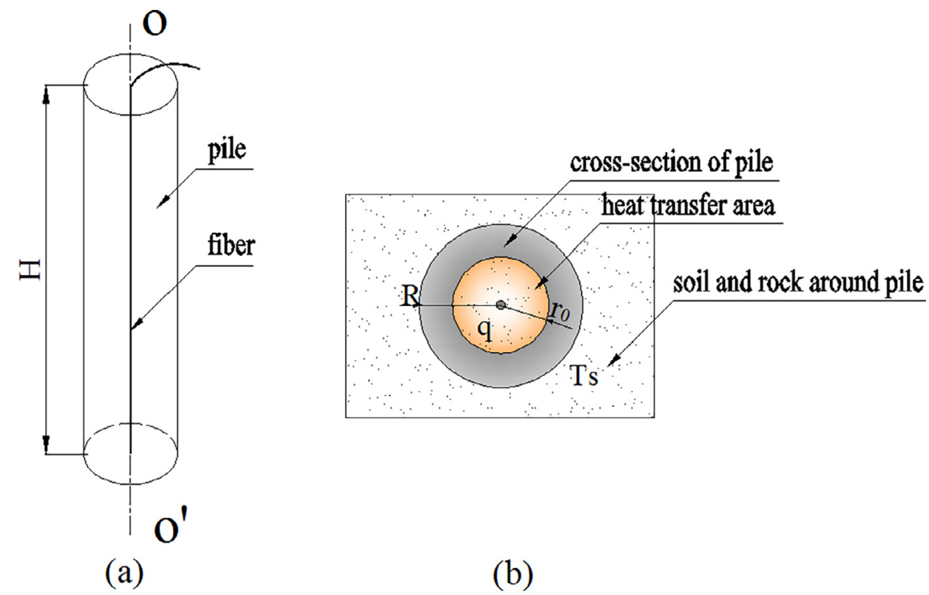
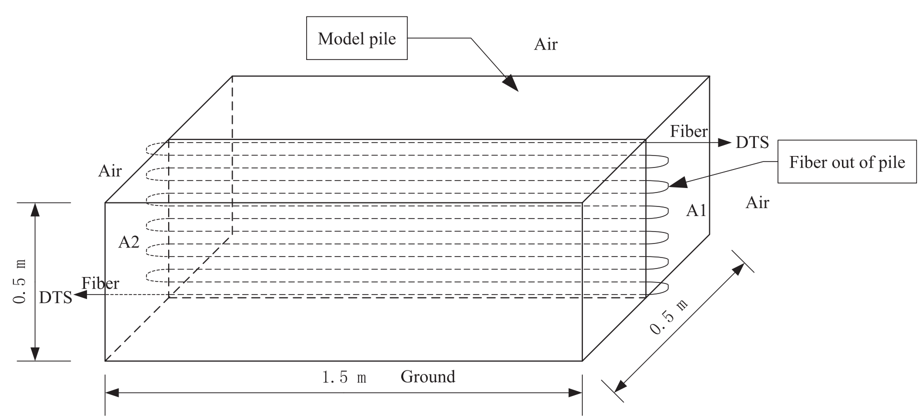
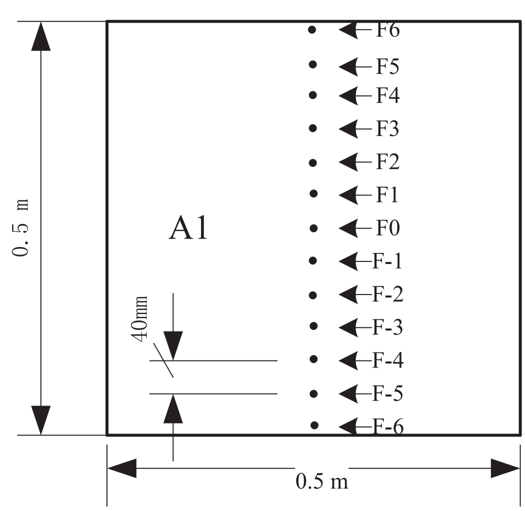


Fig. 1. Analysis model.



(a) Model pile with implanted optical fiber sensors



(b) Arranged fibers with their marks

Fig. 2. Model pile with implanted fiber sensors.