

# Experiment study on constraint condition of distributed sensing optical fiber in deformation measure of soil

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**Abstract.** Although the optical fiber sensing technology has been successfully applied in the geological and geotechnical engineering field, there is a deformation discrepancy between the sensing optical fiber and the rock and soil to be measured in the actual project, which has a greater impact on the monitoring results. The influences of constraint condition with optical fiber are simulated in test, the deformation coordination between the optical fiber and soil is studied through comparative test analysis. The relationship between optical fiber and load is established, as well as the relationship between actual soiled formation and load.

## 1. Introduction

Fiber-optic sensing technology appeared in the 1970 of the 20th century with the development of optical fiber communication technology and the rapid development of a kind of light as a carrier, fiber optic media, sensing and transmitting external signal of new sensing technology[1-3]. Fiber optic sensors have many advantages, such as resistant to electromagnetic interference, waterproof and damp proof, corrosion resistance and long durability and many other advantages, which is suitable for use in complex geotechnical engineering monitoring environment[4, 5]. Another notable characteristics of optical fiber sensor is small volume, light weight, ease of installation layout, having little impact on the material properties of the monitoring object and mechanical parameters, being suitable for condition monitoring of rock mass and structure and the test evaluation[6]. In addition, the optical fiber sensing technology with fiber optic signal transmission, which has the low propagation loss, easy to implement remote signal transmission. Optical fiber bandwidth is large, through the sensor multiplexing capabilities of multiple sensors can be installed on a single fiber, implement multiple points of monitoring at the same time. It is because of these advantages of the technology of optical fiber sensing, makes its successful application in the geotechnical engineering and geological engineering[7-8].

By more groups of loading test, this paper analyzed the coordination deformation characteristics between the fiber and the soil in different constraint condition, which illustrates the coordination deformation evolution between the fiber and the soil, thus to further establish the coordination deformation mechanism between the optical fiber and the soil.

## 2. Experimental design

### 2.1. Test Device



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A series of loading tests are designed for the study of coordination deformation characteristics between embedment strain sensing optical fiber and the soil. The specifications of experimental model box and counter force frame are as shown in table 1. The model box used 10 mm thick toughened glass as retaining structure, which can monitor the deformation of the fiber through the visibility glass.

**Table 1.** The specifications of experimental model box and counterforce frame.

Caption	Length/cm	Width/cm	Height/cm
Model Box	60	30	30
Counterforce Frame	70	40	55

## 2.2. Sensor Placement

**2.2.1. Optical fiber placement.** Place the model box in the counterforce frame and layer the soil into the box. The thickness of each layered soil is 5 cm. Test the density of each compaction soil with ring sampler method. When the soil reaches fiber laying height, laid the optic fiber close to the glass panel and bound on the two ends of the fiber optical fiber, and then fill the upper soil layer by layer, tamping and leveling.

**2.2.2. Displacement meter placement.** Displacement meter is used to monitor the soil subsidence. The displacement meter was buried in the design depth of the soil, the activity side of displacement meter was buried into the same height which the optical fiber was imbed, the fixed end of displacement meter is fixed in lower surface of the thrust frame upper plate.

**2.2.3. Pressure gauge placement.** After the last layer of soil compaction, decorate the pressure gauge in the surface layer of soil, pressure gauge placed on the surface of the jack, the pressure gauge is used for monitoring the load values, the test process is shown in figure 1.



**Figure 1.** Sensor placement.

## 3. The effect of bound condition of optical fiber on coordinate deformation

### 3.1. Test Procedure

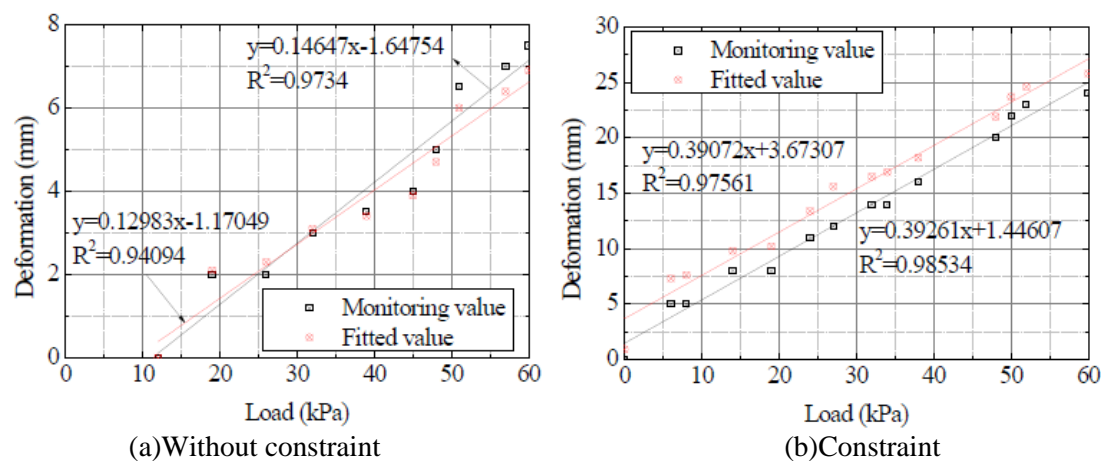
This test was divided into two kinds of working condition, the Steel tight-rope optical fiber embedded in 10 cm deep in the soil and was set in level. On the first condition, both ends of the optical fiber were without constraints. On the other condition, both ends of the fiber fixed on the pillar of reaction frame, used to simulate constraints of fibers buried in soil, which are shown in figure 2.



**Figure 2.** Bound condition.

### 3.2. Results Analysis

The load - deformation curve of optical fiber and the soil on bound condition are shown in figure 3.



**Figure 3.** The load - deformation curve of optical fiber and the soil on bound condition.

Figure 3 show that with the overlying load increasing, the deformation of optical fiber and soil increase gradually in different constraint condition. The deformation of fiber and soil on constraint condition is larger than fiber and soil which without constraints. The deformation of Steel tight-rope optical fiber is larger than the Tight polyurethane optical fiber.

Figure 3 (a) shows that on unconstrained condition, the deformation difference is small between fiber and soil within load 50kPa. While the load is over 50kPa, the deformation difference increases gradually, imposed the same fiber optic deformation is greater than the soil deformation under load. In the same load condition, the deformation of fiber is larger than the actual deformation of soil. Figure 3 (b) shows that on constrained condition, the deformation difference are almost consistent with the increase of the applied load, which larger than unconstrained condition.

In unconstrained condition, it found that both ends of fiber optic which not buried in soil at the beginning of the test both had exposed into the soil, with the increase of load, a certain area on both ends of the fiber optic relative slip has occurred with the soil. Even though the across parts of the optical fiber has good coordination with the soil, but due to both ends of the fiber relative slip with the soil causing parts of the optical fiber unloading, which lead to the actual stress of optical fiber decreased.

With the load increasing, the deformation of fiber optic on constraint condition basically stable, may be due to constraints of optical fiber's ends to prevent the coordination deformation between fiber and soil, Which caused the deformation of fiber not to reflect the deformation of soil. So when laying fibers in actual project, the boundary condition of fiber at both ends cannot be simple constraints, it should be intensive studied and be specified specific constraint methods.

#### 4. Conclusions

The influences of constraint condition with optical fiber are simulated in test, the deformation coordination between the optical fiber and soil is studied through comparative test analysis. The relationship between optical fiber and load is established, as well as the relationship between actual soiled formation and load.

In actual monitoring, the deformation is obtained by calculation formula of the monitoring stress of optical fiber, so the measured deformation of optical fiber is smaller than the real deformation of the optical fiber in test condition, which need further amendment. When laying fibers in actual project, the boundary condition of fiber at both ends cannot be simple constraints, it should be intensively studied and with specifically constraint methods.

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