

VIBRES-system, Improving Inspection Technology of Residual Tensile Load of Ground Anchors

What is Ground Anchor?

Ground anchors are structures that stabilize slopes and other structures by anchoring a tensile material to stable ground and applying tension to its free length portion (**Figure 1**). Ground anchors work to prevent collapse and landslides, and tens to hundreds of them are installed on a single slope (**Photograph 1**). The present number of ground anchors constructed along the expressway in Japan is over 120,000.

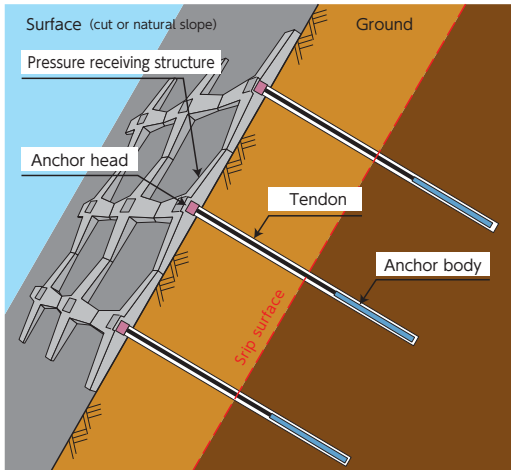


Figure 1 Cross-section of ground anchors

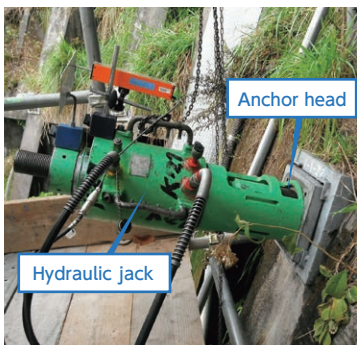


Photograph 1 Example of a slope with ground anchors installed

Challenges in Maintenance and Inspection of Tensile Load of Ground Anchors

Ground anchors, which stabilize slopes though tension, are structures that require inspection of their tensile load. The tensile load of ground anchors has traditionally been inspected by lift-off tests using a hydraulic jack (**Photograph 2**). The lift-off test is a method to measure tensile load by gripping the anchor head at the ground surface and pulling it with a hydraulic jack (**Figure 2**).

The residual tensile load of ground anchor is usually measured by the lift-off test with heavy weight center hole jack, which sometimes requires a temporary scaffold and typically requires time and costs (**Photograph 3**). Therefore, the development of simple and safe tensile load measurement technology to replace the lift-off test has been demanded.



Photograph 2 Lift-off test

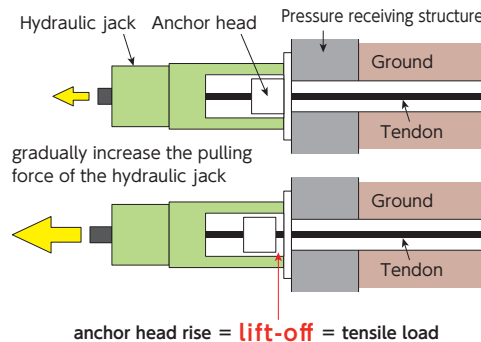


Figure 2 Principle of lift-off test



Photograph 3 Example of a temporary scaffold

Principle of VIBRES-system

The free part of a tensioned tendon vibrates at a higher frequency under high tension and at a lower frequency under low tension, like a guitar (**Figure 3**). The relationship between tension and vibration (resonance) frequency is explained by Eq. (1). Since the free length of the tendon and its linear density are known from the design drawings, the tensile load can be determined if the vibration (resonance) frequency is measured. VIBRES-system is based on measuring the vibration (resonance) frequency of tendon free length, which changes depending on the tension.

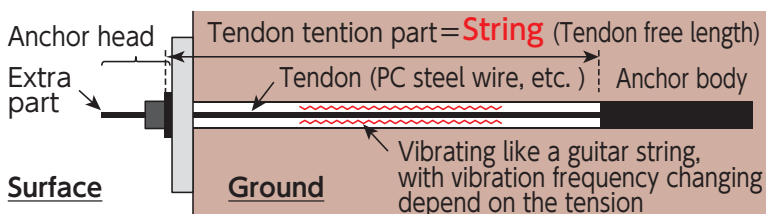


Figure 3 Schematic structure diagram of ground anchor

●Equation relating tension and vibration frequency

$$T = 4 \times L^2 \times f^2 \times \mu \quad \dots (1)$$

T : tension (N)

L : tendon free length (m)

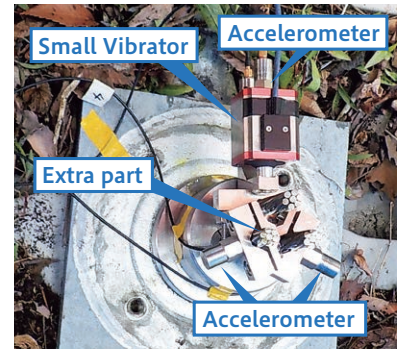
f : vibration (resonance) frequency (Hz)

μ : line density (kg/m)

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Method of Measuring Tensile load by VIBRES-system

Because the tendon free length of ground anchor is located in the ground, its vibration frequency cannot be measured directly. Therefore, in VIBRES-system, a small vibrator and accelerometer are attached to the extra part of the anchor head (**Photograph 4**). The waveform generated by the vibrator is a sweep waveform whose frequency of a sinusoidal wave increases continuously with time (**Figure 4**). The lower part in **Figure 4** shows an example of measurement data. We can easily understand the resonance frequency from the received waveform. We consider the measured resonance frequency as the natural frequency of the tendon tension part and calculate the residual tensile load by using Eq. (1).



Photograph 4 Installation condition

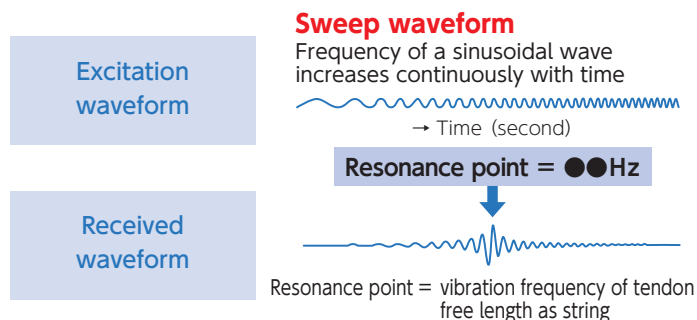
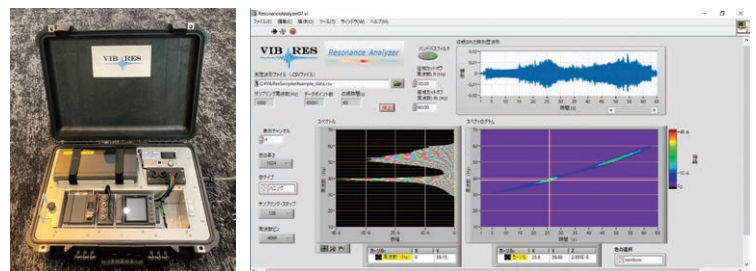


Figure 4 Extension / Received waveform of VIBRES



Photograph 5 Measurement unit and analysis results display

For the measurement work, in addition to a small vibrator (about 400 grams in weight) and an accelerometer (about 30 grams in weight), a measurement unit and a laptop are used. The measurement unit is housed in a 30 cm × 40 cm portable case. By connecting to the laptop installed analysis software, can measure tensile load of ground anchor (**Photograph 5**). The measurement time for tensile load of VIBRES-system is 120 seconds per test, which is shorter than conventional lift-off test.

VIBRES-system does not require large equipment or temporary scaffold used conventional lift-off test, which makes it possible to shorten the measurement time and efficiently determine the tensile load. Moreover, because tension is not applied to the anchor head, there is no risk of the ground anchor fracturing and jumping out, improving safety for workers and third parties such as passing vehicles.

Accuracy of Estimated Tensile Load

The relationship between residual tensile loads estimated from the vibration method (P) and those measured by the lift-off test (P_e) is approximately 1:1, and the error of P with respect to P_e is within $\pm 15\%$ at most (**Figure 5**).

VIBRES-system is a groundbreaking and original technology that achieves more efficient and safer inspection by using vibration to measure tensile load of ground anchors.

※VIBRES-system is based on technology jointly developed by Our company, OYO corporation, Gifu University. (Japanese Patent No. 6283439)

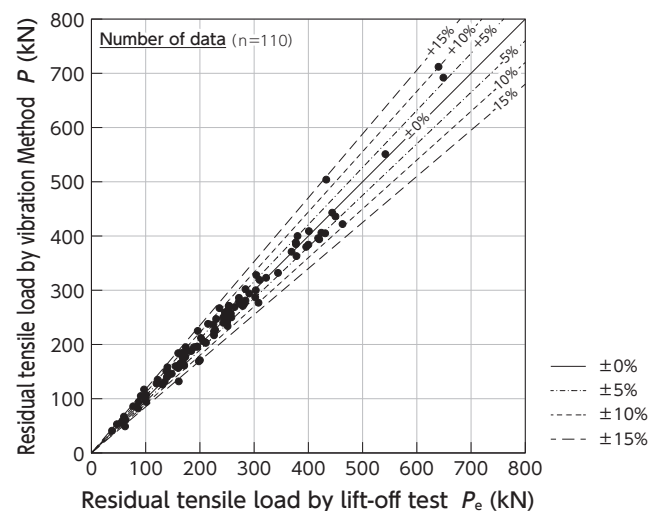


Figure 5 Comparison of tensile load obtained by lift-off test and VIBRES-system

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