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In situ ultrasonic method for estimating residual tension of wedge fix type anchors

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HIGHLIGHTS

- The maximum amplitudes of each of those reflected waves are compared.
- Average maximum amplitude (WRL1) can detected residual tensile.

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ABSTRACT

Good maintenance of ground anchors installed along the slopes and the cuts of expressways is very important to keep those slopes and cuts stable and safe. In this research, nondestructive method which is a cheaper and quicker than extant method, to evaluate residual tension of ground anchors is introduced. Ultrasonic waves reflected back from the upper and lower surfaces of the bearing plate are recorded in the waveform and the maximum amplitudes of each of those reflected waves are compared. While comparing the average maximum amplitude of each reflected wave with corresponding tensile load, a good linear increasing trend is observed when 1st reflected wave from the lower surface of the bearing plate (WRL1). Comparison is made between all the representative average maximum amplitudes of WRL1 of both laboratory and field experiments with corresponding tensile stress (or tension). A generalized equation is then recommended which can be used for predicting residual tension of the anchors.

1. Introduction

In Japan, for the stabilization of slopes and cuts of expressways, 12,000 anchors have been installed till date from 1950s [1]. Among them, lots of Ground anchors installed are with less protection measures against deterioration and ageing. Performance of those old anchors are decreasing and hence slope failures are occurring remarkably [2]. Accidents due to such failures threatens the traffic safety as well as life and property of human beings. Such failure accidents against deterioration can be possibly avoided if a proper maintenance of those anchors is possible.

A good maintenance is just possible if external and internal anchor conditions is known. But no such a method exists which can obtain both of conditions directly and jointly. In addition, as there is no accessibility in the interior anchor structure, the assessment should be conducted through the area located in the surface only, i.e. the anchor head [3]. Therefore, residual tension measurement of anchor without disturbing it is the only way to know the deterioration of anchor. But till now, there is no such established rational method with which residual tension measurement is possible.

Visual inspection is carried out which only gives the information of external condition of anchor especially around the anchor head in general. This is not a reliable method to check the soundness of whole anchor. Another method that has been used is X-ray imaging method [4]. This method gives the insight of the physical condition of the anchor. It cannot however measure the tension of the anchor tendon. This test is time consuming, expensive and requires a special care against radiation. Magnetostriction method has been introduced where magnetic permeability is measured [5]. But as magnetic permeability greatly depends on the slight difference in the shape of the anchor head as well as the properties of the materials, application of this method for various types of anchors is difficult.

Another test, known as "lift-off test" directly estimates the residual tension of anchors. Hydraulic jack is set up at the anchor head and is pulled out against the bearing plate in this method.

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Then, by plotting a graph between hydraulic jack pulling load and displacement of anchor head, residual tension is evaluated. This test is very expensive and requires lots of time in handling and set up of large size apparatus. So, testing of only a few anchors is possible in a long time interval with this apparatus, which is not sufficient for stability analysis of whole area. Moreover, during the test, anchor head or anchor tendon is pulled out from its original position by few millimeter. For the weak and deteriorated anchors, it might jeopardize the safety of the anchor itself [6]. Use of comparatively smaller and lighter weight, SAAM (Sustainable Asset Anchor Maintenance) jack has been developed for lift-off test [7]. However, as more than 120,000 anchors have been already installed, a simplification in device only for lift-off test does not suffice the demands of ready to apply test so that time and cost can be reduced.

A method based on ultrasonic elastic wave has been used for monitoring the stress level in the stranded wires [8]. But this technique does not produce reliable results for anchors installed deep into the ground where the access is limited to one single side. Therefore, it is necessary to develop a method which is fast and easy and can do safe inspection without damaging the original structural condition of the anchors. In addition, it would be better if measurement is possible to conduct on or from the visible portion of the anchor head.

Recently, possible application of ultrasonic wave technique for estimating residual tension of anchor has been thought of. Laboratory tests with ultrasonic wave transmission method have been carried out with nut fix type and wedge fix type anchors for the measurement of tensile loads [9,10]. Accordingly, transmission method is applicable to nut fix type anchors only. But as there is a large disparity in transmitted energy during loading and unloading stages, its field application is yet to be considered. This method cannot be applied to wedge fix type anchors as it requires to set up the transducer at specific position which is very difficult.

Researches on ultrasonic wave reflection method have been carried with different types of anchors in the laboratory [11]. Cumulative as well as individual energy of reflected waves from the upper surface of bearing plate are then compared with the tensile load in loading and unloading steps. Accordingly, no hysteresis is observed between the unloading and second loading steps. This indicates the possible application of this method in the field anchors. But no relationship between the energy of reflected wave and the tensile load has been shown. Also, reflection wave from the lower surface of the bearing plate has not been considered and compared. The main aim of this research is to provide a generalized correlation between residual tension and reflected waves for wedge fix type anchors using ultrasonic wave reflection method. For this, laboratory and field tests are carried out. Properties of reflected waves from the upper and the lower surfaces of bearing plate are then compared to determine the most appropriate reflection wave for the analysis. Finally, a simple correlation between residual tensile load and the determined reflection wave is obtained so that it can be used to predict the residual tension of wedge fix type anchors of the field.

2. Ground anchor types

General layout of the anchor is shown in Fig. 1. In Fig. 2a, outline of the top portion of the anchor is shown. Top portion of the anchor can be divided into anchor head, bearing plate, concrete plate and anchor tendon. Anchor tendon portion can be either a single steel rod or a strand of steel wires. Depending on the type of tendon, the shape of anchor head varies.

For a steel rod tendon, hexagonal shaped anchor head is used (see Fig. 3a). This anchor type is known as nut fix type anchor. Most

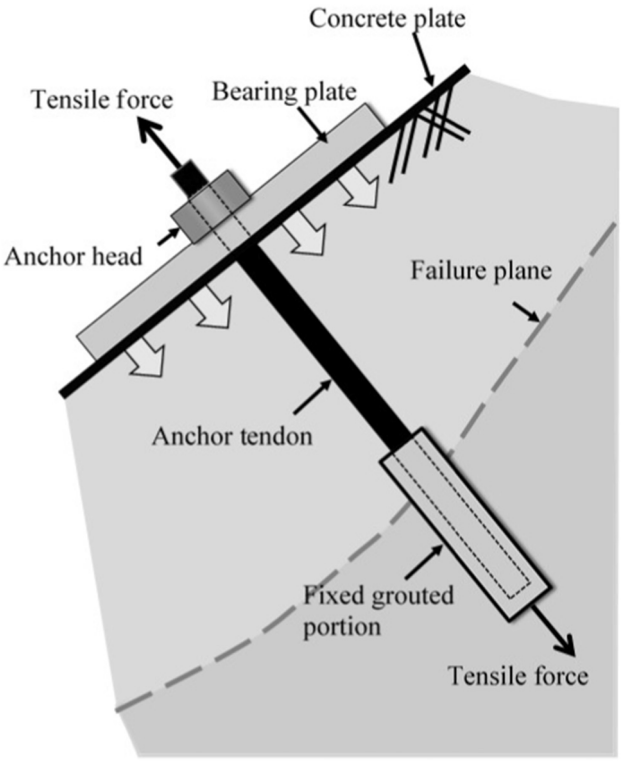

Fig. 1. Outline of ground anchor.

of the anchors installed in the past are of this type and they were in-stalled without proper remediation against water permeation. So, they undergo corrosion induced deterioration.

Another type of anchor is known as wedge fix type anchor (see Fig. 3b). It consists of steel stranded wires which are fixed to the round shaped anchor head by wedges. Most of the recent anchors are of this type and they are strong against corrosion. Depending upon the size and number of stranded steel wires present, this type of anchor is marked as E5-3, E5-4, E5-12, etc. Here, in this research, wedge fix type anchors are only considered.

3. Ultrasonic wave technique

3.1. Ultrasonic wave technique

Ultrasonic wave technique is a nondestructive technique which is generally used to measure the internal defect of the materials. In this technique, at first ultrasonic wave is emitted on the surface of the media and then the properties of either transmitted or reflected ultrasonic waves are studied. In this research, ultrasonic wave reflection method is explained and applied.

3.2. Ultrasonic wave reflection method

In this method, at first an ultrasonic wave is emitted via a transducer placed on the top of the anchor head in such a way that the emitted incident wave passes downward towards the bearing plate and concrete plate along the direction parallel to the axis of the anchor (see Fig. 2b). Incident waves on their way downward, when comes in contact with boundary surfaces are either reflected or transmitted. There are two boundary contact surfaces considered in this research; the upper and the lower surfaces of the bearing plate. Let the waves reflecting back from the boundary contact surface between the anchor head and the bearing plate be WRU (Wave Reflection on Upper surface of bearing plate) and those