Design and Fabrication of an Ultrasonic Testing Probe Holder to Inspect Overhead Anchor Bolts

Prakash Sampath¹, Abdul Azziz Abd Talib², Chin Kian Liew³
Singapore Institute of Technology, 10 Dover Drive, Singapore 138683
¹prakash.sampath@singaporetech.edu.sg
²abdulazziz.abdtalib@singaporetech.edu.sg
³edmund.liew@singaporetech.edu.sg

Abstract

This paper aims to study the design and fabrication of a novel ultrasonic testing probe holder for inspecting different types of carbon steel anchor bolts in an overhead position. There are many factors impacted by the new design of the probe holder, including test results quality, operating cost, inspection time, test efficiency, and inspection safety. The test consistency and time saved to inspect overhead bolts are the most important benefits for the new probe design, as it can obtain high-quality inspection results almost immediately with minimum manual operation required.

Keywords: Ultrasonic testing; Probe design; Anchor bolts; Concrete structures; Overhead inspection

1 Introduction

Anchor bolts play an important role in securing various structures into concrete bodies such as the ceiling of underground tunnels, and the curtain wall of building structures. In recent years, building curtain walls have been widely used in housing construction due to their aesthetics, energy saving and ease of maintenance. The anchor bolts are however subjected to different kinds of loads and are thus prone to different kinds of defects.

Ultrasonic Testing (UT) involves the application of high frequency acoustic waves into a part and reflected waves are recorded. As a simple example, consider a wave transmitted from one flat surface towards an opposite parallel flat surface. A reflected signal from the opposite surface may be attenuated by cracks or pores situated between the surfaces. Additional reflected signals may also be created from these cracks or pores which can be recorded to detect these defects. A point measurement of ultrasonic signal versus distance is called an A-scan. By moving the UT transducer linearly, a B-scan can be recorded. By moving in a continuous up-and-down hatch pattern to cover an area, a C-scan can be recorded. UT has been used widely in the industry and its equipment is well-established [1]. There are
other Non-Destructive Testing (NDT) techniques used to evaluate physical properties of parts by detecting defects in the material without any alteration or damage to the parts [2].

In an application study conducted for the oil and gas industry, UT was performed for an inspection of anchor bolts used at structures in a plant [3]. These anchor bolts were part of a mechanical fastener system used to secure ageing components in the facility. A 4MHz transducer was used with the UT pulser-receiver unit used to inspect anchor bolts which had an original length of 116.5cm. During the UT inspection, a total of 142 out of 448 bolts were measured to have lengths lesser than 116.5cm which were observed to be broken. Although UT could be used effectively to detect broken anchor bolts, the study reported that the difference between bolts that were corroded and broken could not be clearly identified.

UT has also been proven to be a reliable method for bolt inspection in other studies and trials [4]. Inspection of an anchor bolt using UT necessitates a few considerations to achieve desired results. For instance, preparations are required to ensure that the inspected bolt surface is level and smooth, which may require surface sanding or grinding depending on the existing surface condition [5]. There are also other applications and developments of UT for the inspection of steel corrosion in reinforced concrete. Crack widths at the surface of concrete can be detected by non-linear ultrasonic methods [6]. Amplitude attenuation method in ultrasonic testing can also be used to evaluate the corrosion damage of the steel reinforcement in concrete, as there is a relationship between the average amplitude attenuation, the circuit potential values, the instantaneous corrosion rate, and the steel thickness loss [7].

A recent study involved an integrated ultrasonic probe that was permanently attached to an anchor bolt and only required the operator to connect the cable for the probe to function [8]. It was found that repeatable results could be observed in detecting and quantifying defects on inspected anchor bolts. Following this study, an improved design of a UT probe holder is developed for inspecting overhead anchor bolts embedded in concrete.

2 Materials and Methods

2.1 Materials

2.1.1 Bolt Specimens

An example of a bolt designed to fasten a metal base plate to concrete is shown in Figure 1, which can be considered as a generic application for this study. Figure 2 and Figure 3 show samples of a good M12 bolt with a length of 130mm and a similar but defective bolt with a 3mm deep cut notch at 64mm from the bolt end, respectively. These bolts are used to test the fabricated UT probe holder designed.

![Figure 1: An anchor bolt attachment to concrete](image-url)
2.1.2 Fabrication of a Probe Holder

In Figure 4, a newly developed probe holder design is shown using five neodymium magnets secured by countersunk screws to an adaptor module for attachment to an anchor bolt at a metal base plate of a concrete structure. The combined magnetic force can carry the weight of the probe when it is attached to the concrete structure in an overhead position.
The probe holder is installed with a 5MHz contact transducer with a standard LEMO to Microdot cable connection to an ultrasonic testing instrument for signal excitation and data acquisition. This probe frequency selected can provide high signal-to-noise ratio with high sensitivity to material and dimensional changes in the anchor bolt.

2.2 Methods

2.2.1 Ultrasonic Instrument

The ultrasonic instrument used applies acoustic waves that pass through an anchor bolt in the concrete structure and receives partially or fully reflected waves from discontinuities in the bolt or its boundaries. Acoustic waves are introduced into the bolt using an ultrasonic probe attached to the face of the anchor bolt. Following the pulse-echo mode, the same ultrasonic probe is used to receive reflected waves and the results are displayed as a transient wave signal on the instrument. The signal is then examined for discontinuities in the anchor bolt specimen to detect for any defects present.

2.2.2 Inspection with Probe Holder

The newly introduced probe holder can be used to assist the identification of defects at anchor bolts embedded in concrete structures. The probe holder is mounted to a metal base plate of a concrete structure by means of neodymium magnets to ease probe attachment and detachment from an anchor bolt when an inspection process is conducted (Figure 5a) whilst an ultrasonic test signal containing information regarding the bolt’s condition is collected. The probe holder thus simplifies the UT procedure and improves its consistency with no manual adjustments required.

2.2.3 Manual Inspection

Without a probe holder, an operator needs to hold the probe in position, and it can be especially difficult if the bolt is at an overhead structure. The results acquired may be inconsistent and vary depending on the pressure exerted on the probe to the bolt face. Conducting the test manually also increases the time for the inspection process.
Figure 5: Anchor bolt inspections with probe holder
Figure 6: Manual anchor bolt inspections without probe holder

Testing good bolt without defect manually

Amplitude (%) vs Distance (mm)
(Good Bolt)

Testing defective bolt manually

Amplitude (%) vs Distance (mm)
(Defective Bolt)
3 Results and Discussions

3.1 Good Bolt vs Defective Bolt Inspection with Probe Holder

Figure 5b shows the signal of a good bolt without any defects by using a 5MHz transducer with the probe holder. The first backwall echo begins at around 130 mm which corresponds to the length of the anchor bolt. From the graph, the second echo backwall occurs around 275mm. Low background noise can also be observed here especially before the first backwall echo which can minimise the misinterpretation of false positive defects. Compared to the good anchor bolt signal, Figure 5d shows that there is a peak amplitude at approximately 64mm while the first backwall echo is at about 130mm. The wave signal at 64mm corresponds to the cut notch position as shown in Figure 3. These results thus validate the functionality and operation of the designed probe holder for inspecting the anchor bolts.

3.2 Good Bolt vs Defective Bolt Inspection without Probe Holder

Figure 6b and Figure 6d show the results from the manual operating process to inspect the good bolt and defective bolt, respectively. In both graphs here, there is an overall drop in the signal amplitude compared to when a probe holder is applied which indicates that the manual pressure applied on the probe to the bolt is less or inconsistent. Figure 6d also shows that the cut defect can still be detected at about 64mm but there is a drop in the peak amplitude from around 40% when a probe holder is used to 30% when manual inspection is conducted. It should also be noted that it was considerably more difficult to obtain consistent signal results with each trial using the manual inspection approach.

4 Conclusions

The main conclusions from the present study can be drawn as follow:

- utilising the designed probe holder prototype helps in simplifying the inspection process and reducing the time taken for overhead anchor bolt inspection
- the probe holder also provides accurate signals instantly with repeatable results compared to the manual inspection method

Acknowledgement

This project is supported by the National Research Foundation, Singapore, and Land Transport Authority under Urban Mobility Grand Challenge (UMGC-L015).
References


