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Case Study

Ground penetrating radar utilization in exploring inadequate concrete covers in a new bridge deck

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ABSTRACT

The reinforced concrete cast in place four span deck of a concrete bridge near Roanoke, Texas, was recently completed. Due to possible construction errors, it was suspected that the concrete covers in the deck did not conform to drawings and specifications. A full scale non-destructive evaluation of the concrete covers was carried out using ground penetrating radar (GPR) equipment. Cover values were determined from the radargram generated from the scan. The estimated covers were plotted on contour maps. Migration data can substitute the drilling based ground truth data without compromising the concrete cover estimations, except for areas with very high cover values. Areas with high water content may result in inaccurate concrete dielectric constants. Based on the results, significant retrofitting of the bridge deck, such as additional overlay, was recommended.

1. Introduction

Ground penetrating radar (GPR) is a non-destructive testing (NDT) instrument, generally used for subsurface imaging of soil, pavement, and concrete and in many other fields. GPR generates electromagnetic energy pulse and sends it to the subsurface through a transmitter antenna. The pulse gets reflected from various types of targets (rebar, voids, etc.) buried in soil, pavement or other structural elements. GPR collects the reflected signal using a receiver antenna. By using the two way travel time and contrast in amplitude of initial and reflected signal, GPR can produce an image of the subsurface.

Use of GPR in evaluating concrete structures was proposed in early 1990s. GPR has been used to find concrete cover and thickness of bridge deck (Hugenschmidt, 2002). GPR has also been widely used for deterioration mapping of old bridge decks with great success by Gacunski et al. (2009) and Parrillo et al. (2005). However, using GPR on a newly placed concrete bridge deck poses some difficulty because of the properties of still immature concrete. Normally, a GPR antenna having frequency of 1.6 GHz is used for deterioration mapping of old bridge decks. In this study, a higher frequency antenna was used to account for the properties of newly placed concrete. The GPR used in this study is from the Geophysical Survey System Inc. (GSSI). The GPR was used with a 2.6 MHz ground coupled antenna. A ground coupled antenna maintains physical contact with the ground or scanning surface at the time of data collection. The high frequency of the antenna facilitates in the production of radar images with higher resolution which is very useful in concrete investigations, especially in clear cover determination

Abbreviations: GPR, ground penetrating radar; AASHTO, American Association of State Highways and Transportation Officials.

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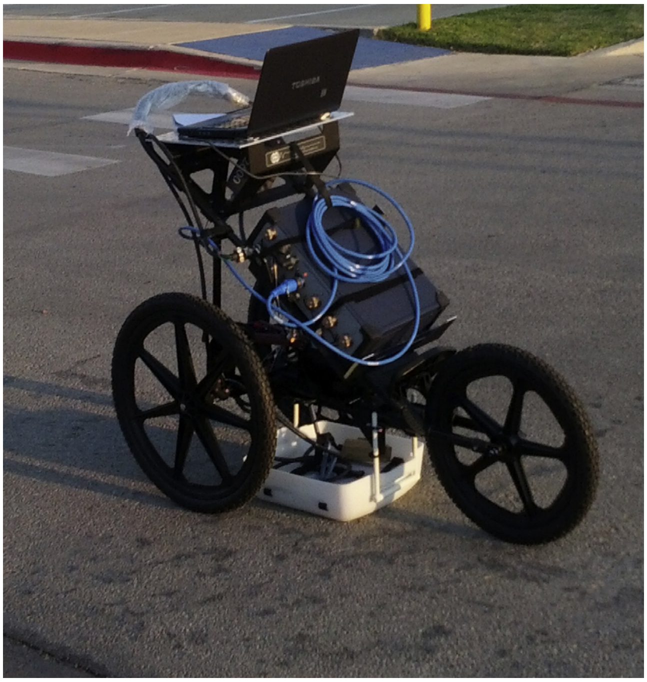

Fig. 1. GPR system.

and locating rebars. A typical cart mounted GPR bridge deck scanning system is shown in Fig. 1. This three wheel GPR system is best suited for scanning short to medium length bridge decks.

2. Materials and methods

The Civil Engineering Department at the University of Texas at Arlington (UTA) was requested to perform a GPR scan on a newly constructed bridge deck. The bridge deck was constructed on December 2012 and the GPR scan was performed on January 2013. Initial inspection indicated that some areas of the bridge deck had concrete covers less than the AASHTO specified value of 64 mm (2.5 in.) (AASHTO, 2010). So, a thorough GPR scan that covered the whole bridge deck was necessary before the bridge was opened to traffic. The main objective of this scan was to produce contour maps of the concrete covers to the upper layer steel reinforcement in the bridge deck. The cover contour map of the bridge would help in determining if any repair or remedial measures were necessary. The location and a full view of the bridge are shown in Fig. 2(a) and (b).

The bridge deck investigated herein is located in the City of Roanoke, Texas (Fig. 2(a) and (b)). The bridge has four spans having lengths of 24.4 m (80 ft), 54.9 m (180 ft), 54.9 m (180 ft) and 36.6 m (120 ft), with a total length of 170.8 m (560 ft), with a skew angle of 60°. The width of the bridge deck is 12.2 m (40 ft) including railings. Fig. 3 shows a schematic diagram of the bridge deck. Span-1 and Span-4 are resting on prestressed concrete girders, while Span-2 and Span-3 are resting on Steel girders. There are expansion joints between Span-1 and Span-2 and between Span-3 and Span-4. Span-2 and Span-3 are continuous.

The GPR scan of the bridge deck was conducted on January 11–12, 2013, by UTA personnel in the presence of highway officials. The scanning consisted of two tasks: (1) drilling exploratory holes on bridge deck to find the existing cover in order to validate the GPR data and (2) bridge deck scan by GPR to produce cover contour maps.

The output of GPR scanning is directly related to accurate input of the dielectric property of concrete. In newly placed concrete, the dielectric constant is higher than that in mature concrete. High dielectric constant slows down the radar wave as it propagates through the concrete (Daniels, 2004). On the other hand, radar wave can travel faster in mature concrete where the dielectric constant is lower. The constant for concrete depends on its component materials, among which water is the most significant. As concrete hardens with time, the water in concrete chemically reacts with the cementitious materials. So, amount of water in newly placed concrete is higher than mature concrete. Among all components of concrete, water has the highest dielectric constant of 80 (Daniels, 2004). So, newly placed concrete has a higher dielectric constant which makes the propagation of radar wave difficult. To overcome this problem, a high frequency (2.6 GHz) radar antenna is used. This antenna is capable of investigation up to 150–200 mm (6–8 in.) depth from the concrete surface. This capability is sufficient to produce reliable data for measuring the concrete cover across the bridge deck. The higher radar frequency also means more accurate data acquisition.