EXPERIMENTAL STUDY ON THE ACCURACY OF CRACK DETECTION ON CONCRETE AND ASSESSMENT OF QUALITY OF REPAIRED CONCRETE WITH ULTRASONIC PULSE VELOCITY

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Concrete cracks are frequently discovered in structures made of concrete. They should be avoided because they may result in serious issues. Therefore, the prompt identification of cracks and the implementation of preventive measures are essential for ensuring structural durability. Cracks formed on the concrete cover pave the way for structural problems. The concrete cover varies according to the purpose of the structural member and the environment in which it is exposed. These cracks make the structural member less resistant to weathering, corrosion, and fire. To detect the extent of these visible cracks on plain concrete, it is better to start with a non-destructive test. This method is cost-effective and quick, making it preferable before using more advanced equipment that may be expensive and time-consuming. To detect the extent of these visible cracks that are on plain concrete, the Ultrasonic Pulse Velocity (UPV) Test can be used. The PUNDIT 7 apparatus of frequency of 54 kHz was used to detect the prefabricated cracks of 2cm, 4cm, and 6cm deep while keeping the width of the cracks fixed. Concrete beams of size 100 × 100 × 950mm were used. The accuracy of these crack detections was studied by varying the transducer distances from the crack. Identifying the most effective transducer distance would save time and cost in detecting the cracks by reducing the labour cost involved. For all three depth variations, the effective transducer distance range with high accuracy, higher than 85% was observed for 80 to 140 mm, and the most effective transducer distance was 100 mm with an accuracy of 97.04% for a 2 cm crack, 94.45% for a 4 cm crack, and 98.02% for a 6 cm crack. The identified cracks in any structure should be repaired. Otherwise, it may end in huge structural problems over time. In the market, many filling materials are available to fill cracks. Among various crack-filling materials, cement grout remains the most widely utilized due to its availability and compatibility with concrete. Therefore, in this study, cracks were filled with cement grout, and the efficiency, which is a measure of how much the filling comes closer to behaving as the original concrete, was checked. For cracks with depths of 2cm, 4cm, and 6cm, the percentages of efficiency were 94.39%, 90.90%, and 88.05%, respectively. These results show that cement grout is effective in reinstating the performance of cracked concrete, especially for shallower cracks. This study was focused on varying the depth of cracks while maintaining a constant crack width. For future research, it is recommended to investigate the influence of crack width variation at a fixed depth.

Keywords: UPV, Concrete Cover, Visible Crack, Repaired Crack

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INTRODUCTION

Non-destructive testing is an effective method to evaluate concrete strength without causing damage to structures. If defects are found during non-destructive testing, a structural engineer can repair, maintain, or replace affected materials on existing structures before they deteriorate further. The Ultrasonic Pulse Velocity (UPV) test is a prevalent non-destructive approach for on-site evaluation of concrete properties. By analyzing the propagation speed and attenuation characteristics of ultrasonic waves, insights into the material's uniformity and structural soundness can be obtained. Concrete cracks should be avoided because they may result in serious issues. Cracks in the concrete cover can significantly compromise structural integrity, particularly when exposed to moisture, elevated temperatures, and corrosive agents. Thus, early identification and prompt remediation of visible cracks in plain concrete are vital to preserving structural performance. The pulse velocity method can be used effectively to measure the crack depth of vertical cracks (Kumar et al., 2006). Furthermore, higher measurement accuracy is achieved when ultrasonic pulse velocity crack depth assessment is conducted in unreinforced concrete (Wibowo et al., 2014). Therefore, an experimental investigation is required, focusing on concrete cover with visible vertical cracks. Moreover, accurate knowledge of transducer positioning during crack assessment can enhance efficiency by minimizing time and cost. Hence, identifying the most effective transducer distance that maximizes the accuracy of crack depth detection is essential. Souza et al. (2019), in their investigation, concluded that the parameters of maximum amplitude and total energy of ultrasonic waveform obtained from transducers placed 100 mm from the crack tip were effective in detecting partial infilling of cracks exceeding 25 mm. Accordingly, given the widespread use of cement grout as a crack-filling material, further experimental studies are necessary to evaluate its effectiveness in crack repair. Therefore, this study aims to detect the accuracy of cracks, and determine the quality of repaired concrete, by determining the efficiency of the cracked concrete, to behave as the original concrete.

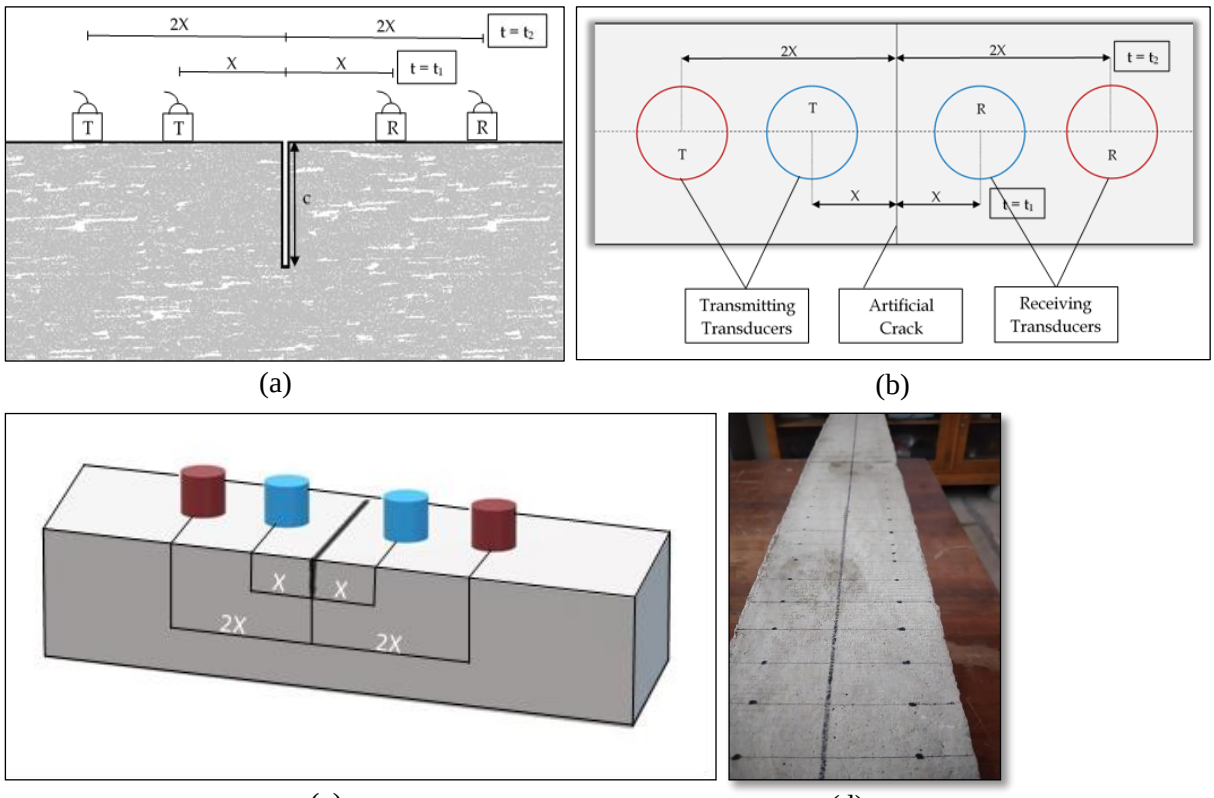
METHODOLOGY

Plain concrete beams (Grade 25 – 1:1.5: 3) with dimensions 100 × 100 × 950 mm with a water-cement ratio of 0.5 were cast. Vertical cracks with crack depth variations of 2 cm, 4 cm, and 6 cm and a width of 5mm were prefabricated at the center of the beam. At 28 days of curing, the concrete specimens were subjected to ultrasonic testing to assess the accuracy of crack depth estimation, based on transit time measurements recorded using transducers positioned at varying distances. Ultrasonic measurements were obtained using a PUNDIT 7 device operating at a frequency of 54 kHz and a voltage of 250 V. The indirect transmission method was employed for all readings. Afterward, cracks in the test specimens were filled with cement grout under gravity. Then, test specimens filled with cement grout were tested after 72 hours to compute the effectiveness of the repaired crack using the UPV values measured by placing transducers at various transducer distances.

In accordance with BS 1881: Part 203: 1986, the indirect transmission method was employed, with transducers placed at varying distances to obtain the required measurements for crack depth calculation. The depth of the crack, denoted as c (in mm), was calculated using the following expression:

$$c = 150\sqrt{\frac{(4t_1^2 - t_2^2)}{(t_2^2 - t_1^2)}}$$

Where,
c : Crack depth (mm)
t_1 : Transit time when X = 150 mm (µs)
t_2 : Transit time when X = 300 mm (µs)



(a) (b)

(c) (d)

Figure 1(a): Side view of positions of transducers, Figure 1(b): Top view of positions of transducers, Figure 1(c): Positions of transducers in 3d, Figure 1(d): Marked transducer distances on the control sample

The accuracy of crack depth, was determined using the following expression:

$$\textbf{ACCURACY OF CRACK DEPTH (\%)} = \left[\frac{\textbf{2A - C}}{\textbf{A}}\right] \times \textbf{100}$$

Where,
C - Computed crack depth (mm)
A - Actual crack depth (mm)

Once the crack is filled with cement grout, it is expected that the repaired section will exhibit properties similar to those of the original concrete. The effectiveness of this restoration, quantified by how closely the repaired section replicates the behavior of the original concrete, was determined using the following expression:

$$\textbf{EFFICIENCY OF CRACK DEPTH (\%)} = \left[\frac{\textbf{2S - R}}{\textbf{S}}\right] \times \textbf{100}$$

Where,
R - Transit time in repaired concrete (µs)
S - Transit time in solid concrete (µs)

RESULTS AND DISCUSSION

Accuracy of crack depth

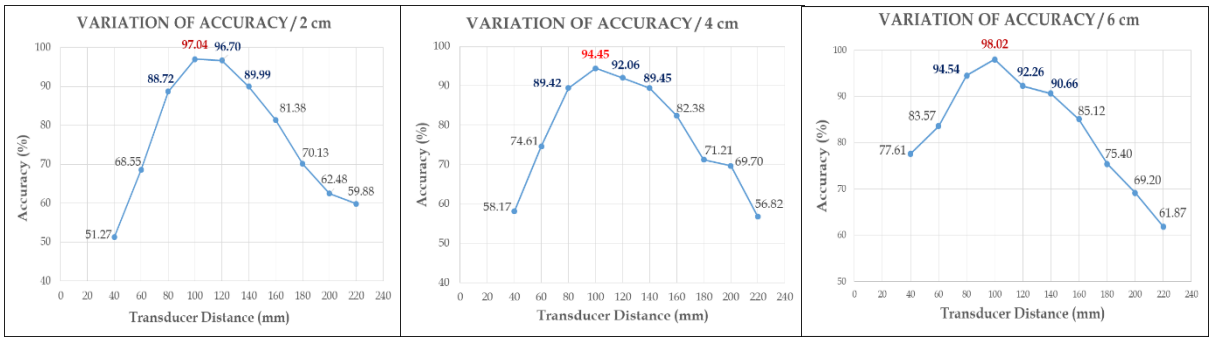


Figure 2: Variation of accuracy of 2cm, 4cm and 6cm crack depths, respectively

Figure 2 shows that the accuracy is high when the transducer distance varies from 80 to 140 mm, for all three crack depths. In this range, the accuracy goes beyond 85% for 2 cm and 4cm crack depths and beyond 90% for 6 cm crack depth. Therefore, the range of effective transducer distance, where the accuracy is high (88.72% to 97.04%) is from 80 to 140 mm, for 2 cm crack depth. Further, for 2cm crack depth, the most effective transducer distance is 100 mm with an accuracy of 97.04%. Similarly, for 4 cm crack depth, the range of effective transducer distance, where the accuracy is high (89.42% to 94.45%) is from 80 to 140 mm, and the most effective transducer distance is 100 mm with an accuracy of 94.45%. Likewise, for 6cm crack depth, the range of effective transducer distance, where the accuracy is high (90.66% to 98.02%) is from 80 to 140 mm, and it can also be seen that the most effective transducer distance is 100 mm with an accuracy of 98.02%.

Efficiency of crack repair

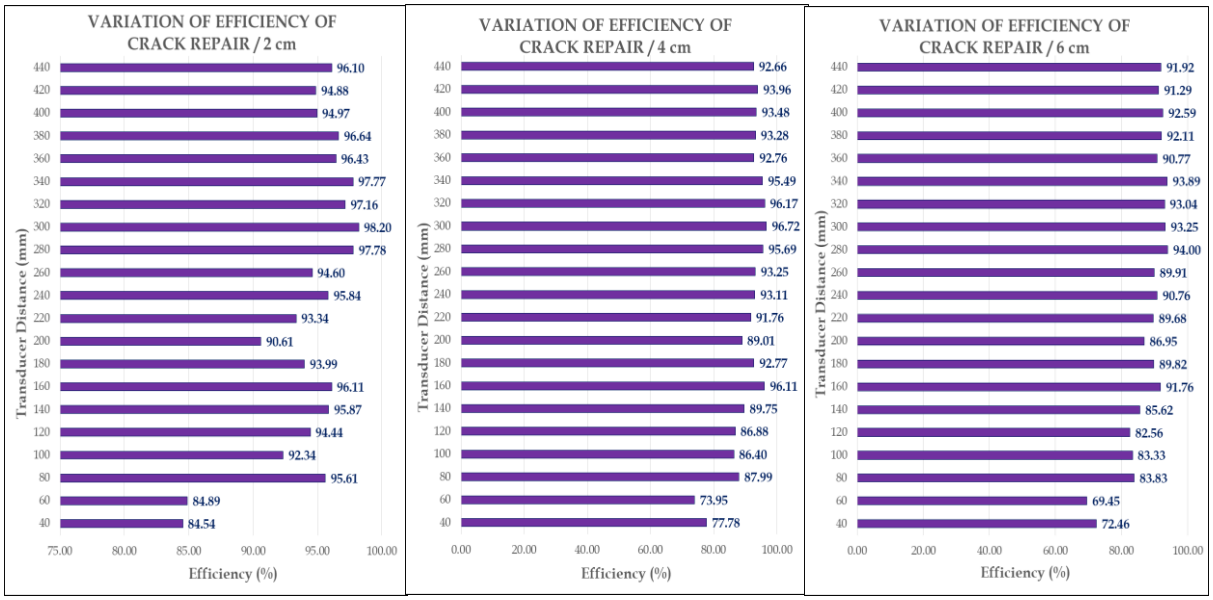


Figure 3: Efficiency of crack repair for 2cm, 4cm and 6cm crack depths, respectively

According to Figure 3, it is observed that the efficiency is typically above 70%for repairing the 4 cm crack with cement grout and mostly above 80% for repairing the 2 cm and 6 cm cracks with cement grout. The average efficiency value computed for 2 cm, 4 cm and 6 cm crack repair is 94.39%, 90.90%, and 88.05%, respectively.

CONCLUSIONS/RECOMMENDATIONS

This study investigated the influence of transducer spacing on the accuracy of ultrasonic crack depth detection and evaluated the efficiency of cement grout as a crack-filling material. The experimental results demonstrated that a transducer distance range of 80 mm to 140 mm is effective across various crack depths; however, a transducer spacing of 100 mm consistently yielded the highest accuracy. Specifically, detection accuracies at this optimal spacing were 97.04% for 2 cm, 94.45% for 4 cm, and 98.02% for 6 cm crack depths. Furthermore, the evaluation of crack remediation performance indicated that cement grout is a viable crack-filling solution, with repair efficiencies of 94.39%, 90.90%, and 88.05% for 2 cm, 4 cm, and 6 cm cracks, respectively. While the efficiency decreases slightly with increasing crack depth, the method remains effective for all tested conditions. Overall, the findings suggest that maintaining an optimal transducer distance significantly enhances detection accuracy and that cement grout provides a reliable means of crack remediation, particularly for shallower defects.

The present study focused on varying the depth of cracks while maintaining a constant crack width. For future research, it is recommended to investigate the influence of crack width variation at a fixed depth, as well as the combined effect of varying both depth and width. Additionally, extending the study to include multiple cracks within the concrete specimen could provide further insights into the interaction effects and detection challenges, especially in more complex structural conditions. The current investigation was limited to vertical cracks; therefore, future work may explore the behavior and detection accuracy of oblique or diagonal cracks under similar testing parameters.

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