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ULTRASONIC PULSE VELOCITY TEST USING BS METHOD AND T-METHOD TO ESTIMATE CRACK DEPTH OF CONCRETE

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Abstract. Ultrasonic Pulse Velocity (UPV) as a non-destructive test is commonly used on concrete crack estimation. There are several methods are applied based on the transducer configuration. Among the methods, BS (British Standard) method and T method was used in this study. On this method, transmitter was fixed at certain distance from crack and receiver was moved at several constant intervals, then crack depth was analyze from the relation between the transducer distance and the transit time curve. This research is conducted to study the accuracy of BS method and T-method in estimating the crack depth of concrete using NDT James Instrument V-Meter M-K IV. Concrete beams were made with artificial crack depth 2 cm, and 4 cm. Transducers 54kHz of UPV Mark IV were set at constant interval. Thus, the comparation of actual depth and experimentally result was analyzed. The study concluded that, the accuracy of the BS method has a better estimation result with a relative error of 27,75% and 35,95%, compare to the T-method that has 79,30% and 79,82% error.

Keywords : concrete crack, BS method, T-Method

1. INTRODUCTION

Concrete becomes the second most consumed material in the world, with average per people almost three tonnes per year [1]. Concrete has been proven to be a prior leading construction material. Commonly, it is obtained by mixing cement, water, sand as fine aggregates, coarse aggregates, and sometimes other substances in a certain ratio [2]. The unyielding nature of concrete makes it tough and durable, it can withstand large loads over a long period [3] It also resists many aspects such as fire, rotting, rusting, and requiring minimal maintenance or repair. When the mechanical properties of concrete decrease significantly, cracks will appear on concrete. Besides the poor workmanship factor, concrete cracks are sometimes caused by overloading and corrosion, Specific cracking patterns that appear in concrete, can be led to a specific reason [4]. Cracks often appear as an early warning of the structure; it indicates failure or a problem in it. The first response is to evaluate the structure strength, to determine the suitable repair or reinforcement of the structure [5].

Ultrasonic Pulse Velocity (UPV) test is one non-destructive test that is applied to estimate concrete cracks. There are five common methods, the SDDW method, Tc-To method, delta method, BS Method, and T method, each one has a specific equation for estimating crack depth. The short distance detour wave (SDDW) method is the simplest method, transmission time and wave velocity are measured by arranging the transmitter and receiver at placing near the side of the crack. In the TC-To method, the transmitter and receiver are placed at a certain distance on the health part of the concrete. Next, both transducers are set between the crack as a center, and the transmission time is measured. The Delta method is the same as the Tc-To method, it measures the transmission time by placing the crack and arranging the transmitter and receiver at a non-symmetrical distance.

British Standard (BS) method is a commonly used method that is recommended by BS4408. The transmission time of the transducer at distance 150 mm and 300 mm between the crack is measured to determine the crack depth [6]. The t method that is also studied in this research is a method of requesting discontinuous time

T at the crack position from the curve (relation between the transmission distance and the transmission time). Both methods use the same indirect method, but have transducer arrangement difference. Herlambang[7], studied about the effect of transducer distance and the accuracy of BS method in estimating the depth of the concrete crack, the accuracy was around 83-92% for a transducer distance of 10 cm. Based on this research, we used a transducer interval of 10 cm. Furthermore, data collection in the T-method is more complex than the BS method. Linggasari [8], observed crack in concrete and compared two methods of measurement which was the BS method and T-method. The research used PUNDIT as testing instrument and showed that there was no significant difference (only 1-2%) between both methods.

The information provided in the previous study indicates, that both methods can be used in measurement because there is no significant difference. However, the study has lack information about accuracies. It is also essential to study both accuracies in measuring the concrete crack, to compare which is the best method. This research aims to study and compare the accuracy of the BS method and the T-method in estimating the crack depth of concrete.

2. METHODS

The specimens are beam-shaped non-reinforced concrete with dimensional of 15x15x60 cm. Then, they were given artificial cracks with depth of 2 cm and 4 cm. The NDT James Instrument V-Meter MK IV is used in this study. The depth of concrete crack is estimated by observing transit time between transmitter and receiver using indirect method. the. Estimation of concrete crack depth measurement measured by Indirect transmission. Two different measuring method are used in this study, which are BS Method and T-Method. British Standard (BS) method is a method where transmitter and receiver are placed in certain x distance between the crack, the transit time is measured as T_1, then both transducers are shifted twice in distance, and the transit time is measured as T_2.

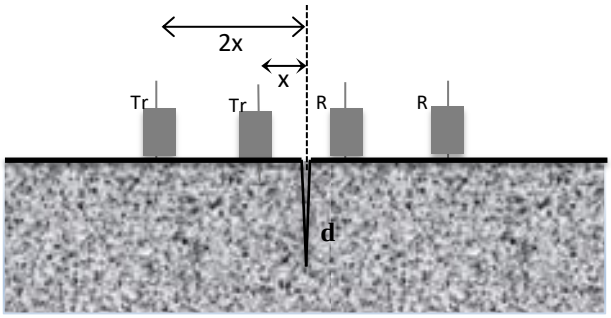

Figure 1. BS method

Depth of crack is calculated from the equation 1 below:

$$d = x\sqrt{\frac{4{T_1}^2 - {T_2}^2}{{T_2}^2 - {T_1}^2}} \quad (1)$$

In this BS method, both transducers are positioned at distance x= 10 cm from the crack then the distance is widened to x= 20 cm (figure 3). Transmission times T_1 and T_2 are then recorded and the depth of crack is calculated refers to Equation 1.

Figure 2. Instrument set up for BS method

The second method is T-method, where transmitter is fixed at a certain distance from the crack as L_1, and receiver is placed and shifted in a constant interval distance of 10 cm (figure 2). Every data of transmission time in each point is collected and plotted, the crack depth is then calculated using equation 2.

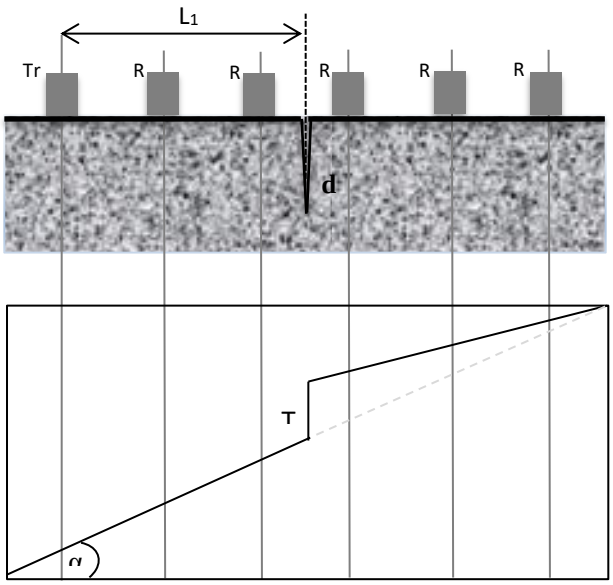

Figure 3. T- method

Depth of crack is calculated from the equation 2 below [9]:

$$d = T.\cot\alpha.\frac{T.\cot\alpha + 2L_1}{2(T.cot\alpha + L_1)} \quad (2)$$

Figure 4. Instrument set up for T-Method

3. RESULTS AND DISCUSSION

The differences between depth crack measured (d-measurement) and actual depth (d-artificial) is stated in error relative. Beam 2 specimen with 40 mm artificial depth has better error relative than beam 1 with 20 mm depth.

Table 1. Summary result of BS-method measurements

Specimen	X (mm)	T_1 (μs)	T_2 (μs)	d-artificial (mm)	d-measurement (mm)	Error relative (%)
Beam 1	10	77,1	150,1	20	27,19	35,95
Beam 2	10	96,1	176,7	40	51,10	27,75

The transmission time and distance data from T-method test are plotted in figure 5 and figure 6. Based on the graph in figure 5, the discontinuous time T for beam 1 is 16,94 μs with the cotangent α of the slope is 2,27. Refer to the equation 2, it is obtained the crack depth is 35,86 mm.

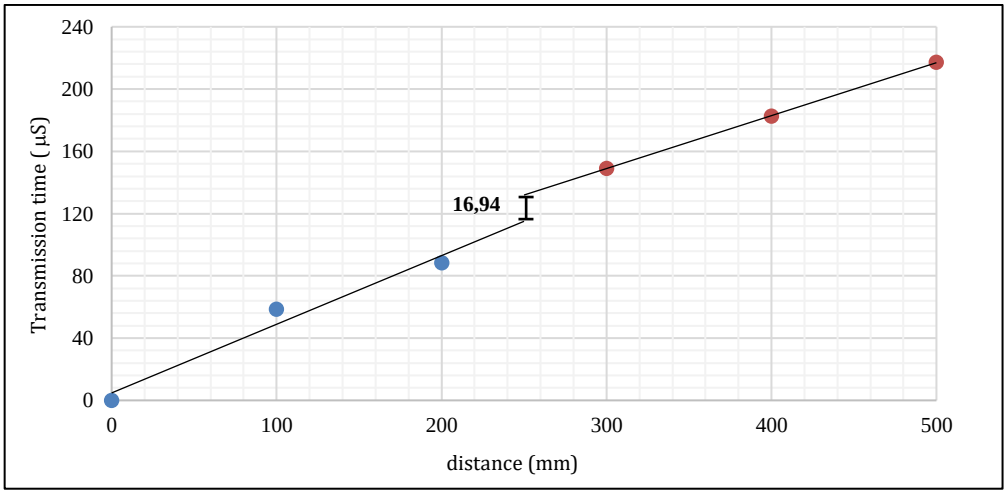

Figure 5. Transmission time of beam 1

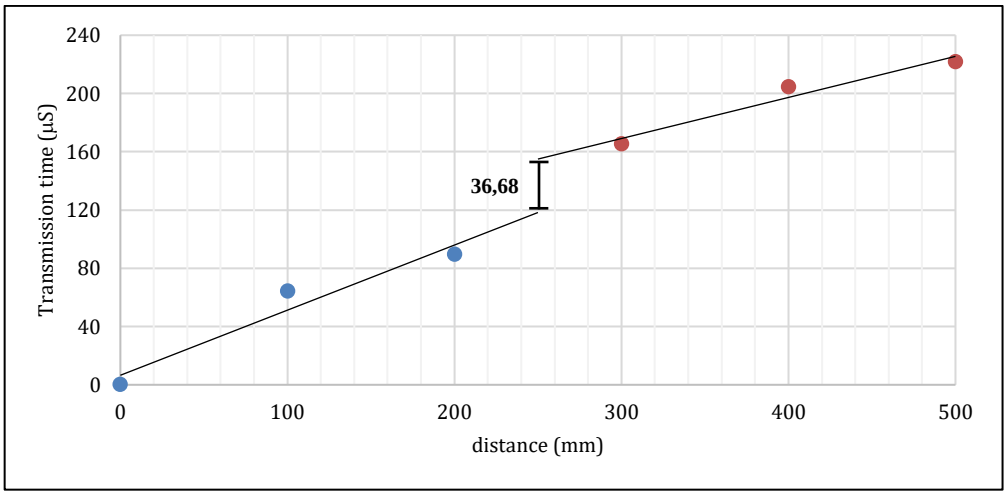

Figure 6. Transmission time of beam 2

Table 2. Summary result of T-method measurements

Specimen	T (μs)	cot α	L_1 (mm)	d-artificial (mm)	d-measurement (mm)	Error relative (%)
Beam 1	16,94	2,27	250	20	35,86	79,30
Beam 2	36,68	2,24	250	40	71,93	79,82

For sample beam 2, from the graphic plot, discontinuous time T is 36,68 μs with the cotangent α of the slope is 2,24. The result of the crack depth is 71,93 mm. Based on the result in table 1 and table 2, it showed that both methods are overestimated the depth of crack. In comparison with Linggasari [8] , the result shows that there is around 27%-33% different from both methods. By using BS method, error relative is 27,75% and 35,95% while by using T-method is 79,30% and 79,82%. The T-method is observed more inaccurate than BS method in estimating depth of the crack. Several possible factors influence this result, besides the lack of the precision of transducer set up. It is also possible due to the wide transducer distance during this measurement. The surface zone concrete predominantly affects the ultrasonic pulse from transmitter to receiver, which may not be represent the the body thus highly subject to errors. The recorded signal probable to fluctuate and gives difficulty during measurements. Thus, it is highly recommended to use an aid tool to assist the transducer during measurements to get the fixed recorded data.

4. CONCLUSION

The research aims to study and compare the accuracy of the BS method dan T-method in estimating the depth of artificial crack concrete beam. The result shows that both methods have different estimation around 27%-33%. The accuracy of the BS method has a better estimation result with a relative error of 27,75% and 35,95%, compared to the T-method which has 79,30% and 79,82% errors. This lack of accuracy is probably caused due to the wider transducer's distance and fluctuation of recorded signals during the measurement. An aid tool as a transducers stabilizer is suggested to be used to obtain better measurement.

5. ACKNOWLEDGEMENT

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