COMPARISON OF ULTRASONIC PULSE VELOCITY TEST RESULTS WITH AND WITHOUT USING TRANSDUCER STABILIZER

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Abstract
Some research on the Ultrasonic Pulse Velocity (UPV) test has not covered much about the problems encountered during the data collection process. Based on experience using UPV test equipment, it is known that instability occurs in reading the test results. This is caused by the inability of the operator, in maintaining the stability of the transducer both in its position and pressure, especially in the measurement with the overhead position. Therefore, in this study a tool was made to make the transducer stable in the test position. Comparison of measurement results shows that, the uncertainty of wave velocity measurement decreases from the range of 4% -17% to 0.2% -0.4%. Meanwhile, the uncertainty of measurement of wave travel time decreased from the range of 0.8% -14% to 0.1% -0.4%. This can be interpreted that, the level of accuracy of measurements using a transducer stabilizer is 99.6% -99.9%. Thus, the use of transducer stabilizers is believed to be able to improve measurement accuracy.

Keywords *: UPV, transducer, stability*

INTRODUCTION

There are 2 types of testing methods used to evaluate the characteristics of a material, namely destructive test and non-destructive test. Both types of testing have their respective strengths and weaknesses. Destructive testing gives more factual results, but if carried out on a building it will be feared to affect the strength of its structure. Non-destructive testing (NDT) is an examination, test, or evaluation performed on any type of test object without changing or altering that object in any way, in order to determine the absence or presence of conditions or discontinuities that may have an effect on the usefulness or serviceability of that object (Hellier, 2003). Ultrasonic Pulse Velocity (UPV) test as a testing of non-destructive methods, has been widely used to evaluate concrete quality. Ultrasonic waves are used in testing of a concrete, by transmitting wave signals with a frequency of 20-150 kHz on the concrete surface. The ultrasonic pulse velocity (UPV) method is based on measurement of the travel time of an ultrasonic wave through concrete over a known path length. The commercially available systems consist of two piezoelectric transducers and electronic circuitry to determine the pulse travel time between the transducers (Dilek, 2009).

According to Woodson (2009), UPV has many advantages including:

a. provides a nondestructive method for evaluating structures,
b. measures the time of travel of acoustic pulses of energy through a material of known thickness,
c. piezoelectric transducers are housed in metal casings and are excited by high-impulse voltages as they transmit and receive acoustic pulses,
d. an oscilloscope in the system measures time and displays acoustic waves,
e. reliable in situ delineations of the extent and severity of cracks, areas of deterioration, and general assessments,
f. capable of penetrating up to 300 feet of continuous concrete with the aid of amplifiers,
g. can be transported easily,
h. has a high data acquisition to cost ratio,
i. can be converted for underwater use.

The UPV method used to examine the homogeneity and quality of concrete is based on propagation of high-frequency sound wave through the material (Singh, 2018). Jepriani (2008), provides accuracy of measurement of concrete cracks in the transducer distance variation of 15.41% - 124.09%. Herlabang, et al (2017), estimated the depth of concrete cracks with variations in transducer distance and type of reinforcement, with accuracy obtained ranging from 13% to 92%. Transducers play an important role in ultrasonic measurements and affects accuracy.

Besides having many advantages, UPV is also has weaknesses. Because of its sensitivity of this method, caution is needed in the transducer placement. The accuracy of the UPV test results is affected by the placement of the transducer during the measurement. The precise and stable position of the transducer will result in a valid reading of the data. Transducer instability, mainly caused by the operator's inability to hold the transducer position, and also the fatigue factor caused by repeated testing. Testing conditions are increasingly difficult when conducting overhead tests where the operator must look up and while trying to maintain the transducer position. Corrections of the UPV test results due to instability of the transducer, have been carried out by Budio, et al (2016). In one type of specimen, the wave velocity read on a UPV device has a wide spread of data. This shows the inconsistency of the reading caused by the unstable position of the transducer. Although the final conclusions of the study did not produce a correction formula.

Based on the description above, measurement accuracy is related to transducer placement. A transducer stabilizer will be able to maintain the position of the transducer during measurement, especially in tests with an overhead test position for a long period of time. A good and stable contact transducer on the surface of the test concrete is expected to provide accurate measurement results. The purpose of this study is to compare the results of UPV test measurements with and without the use of a transducer stabilizer.

RESEARCH METHODS

This study compares the reading of the wave velocity and time of the UPV device, with and without the use of a transducer stabilizer. The type of UPV tool used is NDT James Instrument V-Meter MK IV (Figure 1).

Figure 1. NDT James Instrument V-Meter MK IV

There are three basic ways in which the transducers may be arranged, as shown in Figure 2, these are: direct transmission, semi-direct transmission, and indirect transmission. In direct method (figure 2a), the path is clearly defined and can be measured accurately, it is the most reliable from the point of view of transit time measurement. This setting is recommended used wherever possible for assessing concrete quality. The semi-direct method (figure 2b) can sometimes be used satisfactorily if the angle between the transducers is not too great, and if the path length is not too large (Bungey, et al, 2006). The attenuation of the transmitted pulse sometimes makes no clear signal received. The path length is also less clearly defined, but it is generally regarded to measure this from centre to centre of transducer faces. It makes the semi-direct transmission is less effective than direct method. The indirect method (figure 2c) is definitely the least satisfactory compare to previous method. The exact path length is uncertain. Both transducers is placed on same surface in a certain distance. The transmitter will receive signal that will be predominantly influenced by the surface concrete, which may not be representative of the body. This method is dependent upon scattering of the pulse by discontinuities and the pulse velocity.

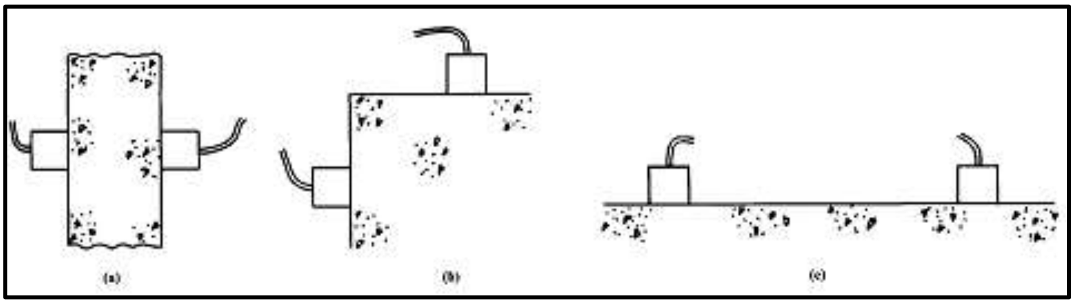

Figure 2. UPV test method

These three methods will be used in this study together with a transducer stabilizer. The transducer stabilizer is a self-designed, made of acrylic material with a thickness of 8 mm. A pair of iron clamps were added as a lock. The holes in the acrylic plane, have the same diameter as the diameter of the transducer used. The distance between the center of the hole is designed to be 10 cm (Figure 3). The distance setting is based on the results of previous studies (Herlambang, et al, 2017), that the best accuracy of 92.07% is obtained at a transducer distance of 10 cm.

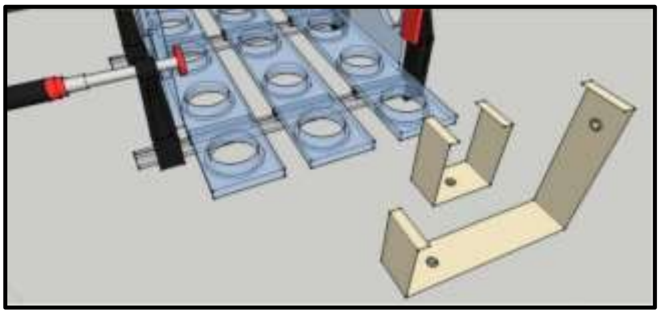
Figure 3. Design of a transducer stabilizer

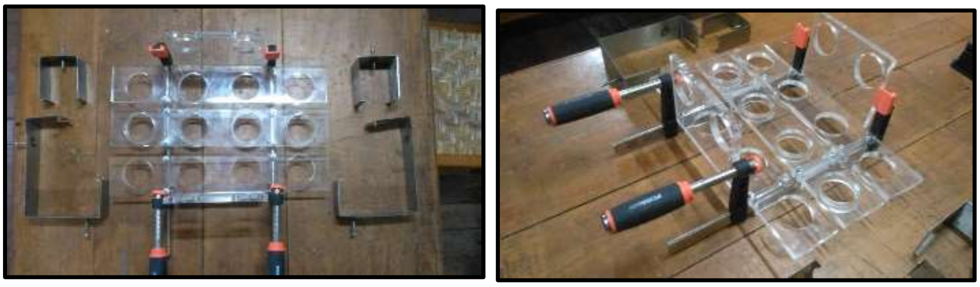
Figure 4. Transducer stabilizer

In this study, the design of the device was not yet perfect, but the application of the idea was felt to provide stability to the transducer. Some weaknesses that are still felt when using this tool are: practical loading and unloading so that it still takes quite a long time in the settings, still has a fairly heavy weight so that it is quite tired in loading, and still in the form of 3 separate elements that can still be put together to achieve a better level of practicality (Figure 4).

The test sample is the structure of “bale bengong” at the Bali State Polytechnic campus. Measurements were made 30 times for each test position, direct test, semi-direct test, and indirect test. The installation of the transducer stabilizer on the beam, in the overhead test position and the indirect test method can be seen in Figure 5. The two transducers are placed on the bottom of the beam, and locked to the stabilizer.

Figure 5. Installation of transducer on the stabilizer

Next, the value of the wave velocity and time are analysed descriptively to obtain the average value and the standard deviation. Both statistical parameters will later become indicators of the stability of the measurement data. Relative uncertainty (RU) is a comparison between absolute uncertainty and measurement results ($\Delta x/x$) and expressed in percent (%). The smaller the relative uncertainty, the higher the accuracy achieved in the measurement (Riskawati, et al, 2018).

RESULTS AND DISCUSSION

The data obtained are propagation velocity (v) and ultrasonic wave travel time (T) generated from the test without and with a transducer stabilizer. From 30 measurements, the data shown in Table 1 and 2 are obtained.

Table 1. Measurement results without transducer stabilizers

Number of Test	Test Method					
	direct		semi-direct		indirect	
	v (m/s)	T (µs)	v (m/s)	T (µs)	v (m/s)	T(µs)
1	3082	50.3	2591	32.8	1038	96.3
2	3100	50.0	2615	32.5	1095	75.7
3	3125	49.6	2623	32.4	1495	69.2
4	3110	49.7	2640	32.2	1792	55.8
5	3131	49.5	2632	32.3	1792	55.8

6	3144	49.3	2648	32.1	1805	55.4
7	3150	49.2	2656	32.0	1825	54.8
8	3157	49.1	2681	31.7	1821	54.9
9	3157	49.1	2665	31.9	1835	59.5
10	3150	49.0	2665	31.9	1838	54.4
11	3163	48.9	2673	31.8	1855	53.9
12	3170	49.3	2681	31.7	1852	54.0
13	3157	49.0	2964	32.2	1873	53.4
14	3150	48.9	2648	32.1	1859	53.8
15	3163	49.1	2640	32.2	1862	53.7
16	3170	49.2	2673	31.8	1855	53.9
17	3176	49.0	2693	31.5	1736	57.5
18	3183	48.9	2707	31.4	1736	57.3
19	3183	48.8	2716	31.3	1739	57.5
20	3163	48.7	2724	31.2	1748	57.2
21	3176	48.7	2778	30.6	1751	57.1
22	3183	49.0	2824	30.1	1616	61.9
23	3176	48.8	2872	29.6	1672	59.8
24	3170	48.7	2981	29.4	1667	60.0
25	3183	48.8	2921	29.1	1715	58.3
26	3163	48.9	2911	29.2	1712	58.4
27	3176	48.8	2901	29.3	1721	58.1
28	3170	48.9	2911	29.2	1727	57.0
29	3176	48.8	2921	29.1	1730	57.8
30	3176	48.8	2962	28.7	1736	57.6
Σ	91934.000	1472.80	82517.000	933.300	51498.000	1770.000
mean	3064.467	49.093	2750.567	31.110	1716.600	59.000
SD	520.591	0.389	127.106	1.291	195.449	8.429
% RU	**16.988**	**0.791**	**4.621**	**4.149**	**11.386**	**14.286**

Based on Table 1, it can be seen that the results of wave velocity measurements in UPV settings without transducer stabilizers produce a relative uncertainty (RU) of 4% - 16%, while for wave travel time is 0.7% - 14%. The percentage of measurement relative uncertainty can be used as an indicator in seeing the stability of the instrument reading. The instability of instrument reading is expected to arise due to the fatigue factor of the instrument operator, so the position of the receiving transducer often shifts and affects the UPV reading.

To overcome this, the transducer stabilizer is designed to hold the position of the receiving transducer at the position of the test point. The test results show an increase in the stability of the instrument readings as shown in Table 2 below. In the measurement of propagation velocity and wave travel time, the percentage of uncertainty is 0.1% - 0.4%.

Table 2. Measurement results with transducer stabilizers

Number of Test	Test Method					
	direct		semi-direct		indirect	
	v (m/s)	*T* (μs)	*v* (m/s)	*T* (μs)	*v* (m/s)	*T* (μs)
1	3144	49.3	3114	27.3	1802	55.5
2	3144	49.3	3125	27.2	1805	55.4
3	3144	49.3	3137	27.1	1805	55.4
4	3140	49.2	3125	27.2	1802	55.5
5	3157	49.1	3137	27.1	1802	55.5
6	3150	49.2	3125	27.2	1802	55.5
7	3157	49.1	3148	27.0	1805	55.4
8	3144	49.3	3137	27.1	1808	55.3
9	3144	49.3	3148	27.0	1805	55.4
10	3150	49.2	3160	26.9	1805	55.4
11	3150	49.2	3137	27.1	1808	55.0
12	3150	49.2	3148	27.0	1808	55.3
13	3138	49.4	3148	27.0	1812	55.2
14	3150	49.2	3148	27.0	1808	55.3
15	3150	49.2	3137	27.1	1818	55.0
16	3150	49.1	3148	27.0	1815	55.1
17	3144	49.3	3148	27.0	1808	55.3
18	3138	49.2	3172	26.8	1815	55.1
19	3157	49.2	3148	27.0	1808	55.3
20	3144	49.3	3137	27.1	1815	55.2
21	3150	49.2	3148	27.0	1808	55.3
22	3144	49.2	3148	27.0	1812	55.1
23	3150	49.3	3160	26.9	1808	55.3
24	3138	49.2	3160	26.9	1815	55.0
25	3150	49.4	3148	27.0	1808	55.2
26	3150	49.2	3160	26.9	1818	55.3
27	3150	49.2	3160	26.9	1812	55.2
28	3144	49.3	3160	26.9	1808	55.1
29	3150	49.2	3160	26.9	1812	55.3
30	3150	49.3	3160	26.9	1808	55.3
Σ	94421.000	1477.1	94391.000	810.5	54265.000	1658.20
mean	3147.367	49.237	3146.367	27.01	1808.833	55.273
SD	5.236	0.076	13.283	0.11	4.654	0.151
% RU	**0.166**	**0.155**	**0.422**	**0.42**	**0.257**	**0.273**

Table 3 below shows the relatively small percentage of error value indicates that the measurement using a transducer stabilizer is capable of producing accuracy of 99.6% - 99.9%. This stable data recording is expected to improve measurement accuracy.

Table 3. Comparison of measurement relative uncertainty (%)

Data	direct test		semi-direct test		indirect test	
	with	without	with	without	with	without
Velocity	16.988	0.166	4.621	0.422	11.386	0.257
Time	0.791	0.155	4.149	0.425	14.286	0.273

CONCLUSIONS

The use of transducer-receiver stabilizers has been shown to increase measurement accuracy by increasing measurement accuracy and reducing the relative error rate in measuring wave velocity and wave travel time.

ACKNOWLEDGMENTS

Thank you to the Bali State Polytechnic in particular the Research and Community Service Unit who has been willing to fund this research through DIPA in Fiscal Year 2019.

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