Ultrasonic Pulse Velocity Tester (UPV)

Standard: EN 12504-4, ASTM C597, BS 1881-203, ISO 1920-7, ASTM D2845

1 Introduction

Ultrasonic pulse velocity (UPV) test is one of the common and non-destructive methods to evaluate quality and strength of concrete structures with two accessible surfaces.

The ultrasonic device generates electrical pulses and then by the transmitter transducers, these electrical pulses are converted into waves with a frequency between 20 and 250 kHz, and after passing through the concrete samples, the waves are received by a receiver transducer and as an electrical pulse. Then the time taken for the waves to move in the concrete sample is measured by the device with an accuracy of ±0.1 microsecond. Finally, the pulse velocity (V) in meters per second is obtained from the following equation:

$V=L/T$

where in:

L = path length

T = travel time is the time taken by the pulse to pass through the length L.

Figure 1 shows the schematic representation of the operation of the ultrasonic Pulse Velocity Tester.

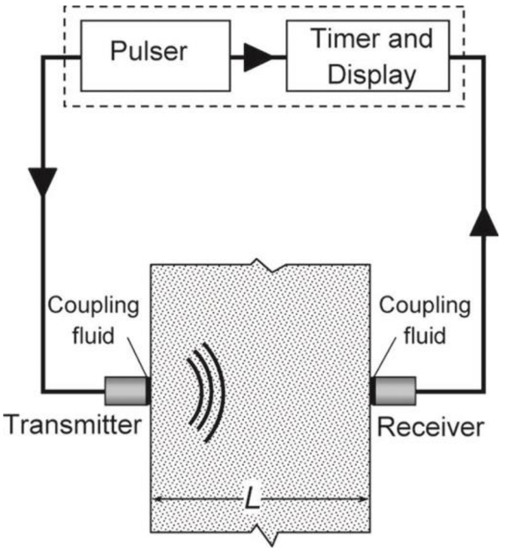


Figure 1 - Schematic diagram of the device's operation

2 Objectives

This test is used for the following purposes:

1. Evaluation of concrete quality
2. Presence of cracks and other defects such as pores
3. Evaluation concrete properties over time
4. Estimation of concrete strength

5. Determining dynamic modulus and Poisson's coefficient (in small strains)
6. Measuring the surface crack depth
7. Measuring the depth of layers

3 Technical specifications of the device and its accessories

- Measuring travel time from 0.1 to 2000 microseconds with an accuracy of 0.1 microseconds
- Pulse rate 1, 3, 5 per second, selectable
- Maximum output voltage 500 volts
- Frequency range 24 to 250 kHz
- connection to an oscilloscope
- Internal rechargeable battery with a capacity of 2800 mAh

The kit includes a portable ultrasonic device, two transducers, and a calibration rod to adjust readings before each test. The device and accessories are shown in Figure 2.

Figure 2- The device and its accessories

One of the important things in this test is a good connection between the surface of each transducer and the concrete surface with using materials such as grease or gel.

4 Transducers arrangements

As shown in Figure 3, there are three main transducers arrangements:

A) direct method

b) semi-direct method

c) Indirect method

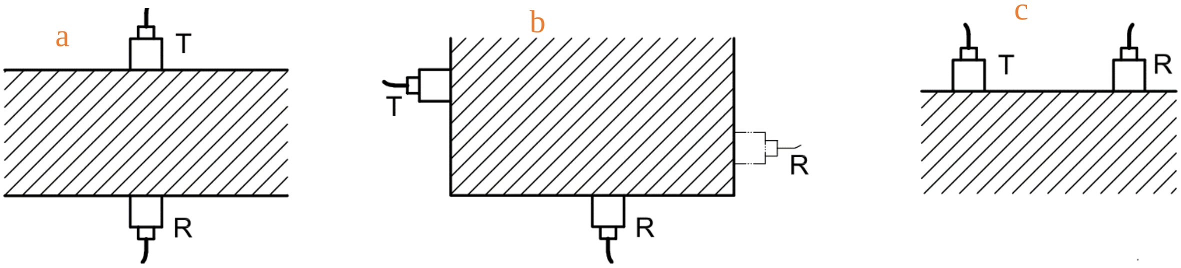


Figure 3- transducers arrangements: (a) direct (b) semi-direct (c) indirect

While the maximum pulse energy is transmitted when transducers are opposite, the direct method is the most reliable method from the point of view of travel time measurement. In some cases, it is not possible to access the opposite surfaces, so this test can be done with adjacent surfaces (semi-direct method) or on one surface (indirect method).

5 Test method

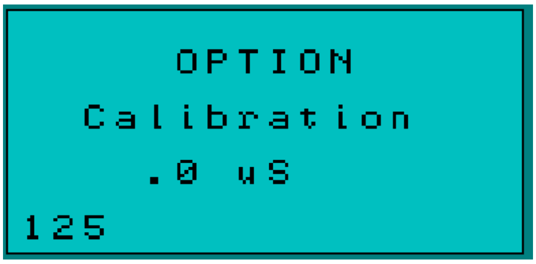
5.1 Device calibration check

Step 1: Turn the device on and apply a small amount of gel on the surface of the transducers.

Step 2: Use the calibration rod to check and adjust the travel time as the calibration number on the rod. An example of a calibration rod is shown in Figure 4.

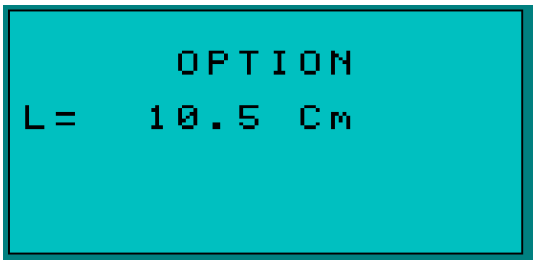
Figure 4 - Calibration rod

Step 3: To calibrate the device, the following steps should be done. When the device is stopped, go the settings menu by holding the start button. Select the calibration settings by pressing the up and down keys. Then use the up and down keys to select the travel time as indicated on the calibration rod. The display shows the travel time that should be equal to the value on the calibration rod.



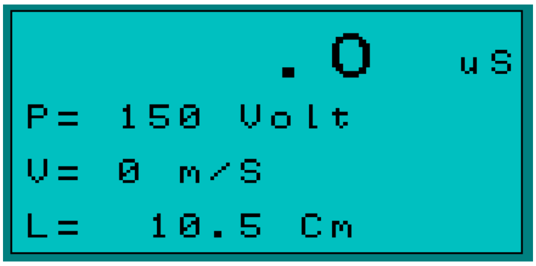
5.2 Pulse velocity measurement

Step 1: To determine the pulse velocity, it is necessary to measure the length of the path between the two transducers and store on device. To do this, enter the settings menu. Select the "path length" parameter setting. Enter the length of the path by pressing the up and down keys.

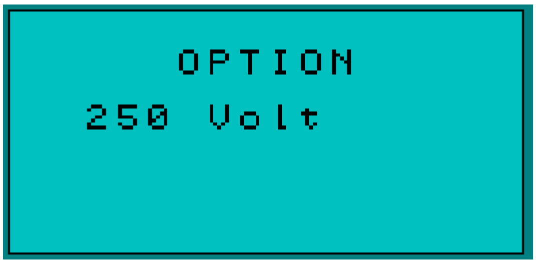


Step 2: Place the transducers on the opposite surfaces of the concrete with slight pressure, and hold for a while to take readings, wait for a steady reading to appear on the device's display.

Step 3: Record the reading, which is the travels time (T) in microseconds (μs) and the pulse velocity (V) in meters per second.



It is better to increase the output voltage in the settings menu for long path or low-quality samples.



5.3 Estimation of surface crack depth

Use the following equation to measure the crack depth:

$$C = x \times \sqrt{\frac{(4t_1^2 - t_2^2)}{(t_2^2 - t_1^2)}}$$

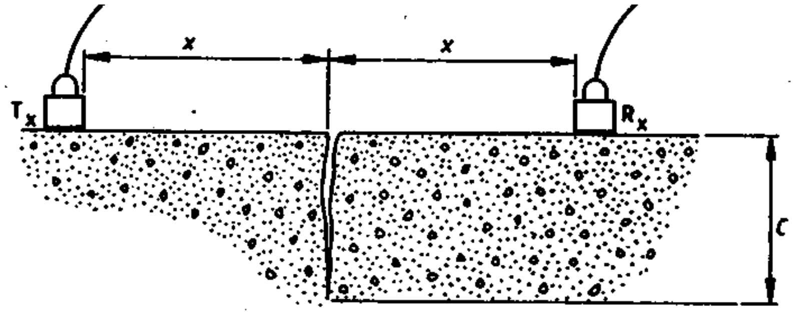


Figure 5- Crack depth calculation

First, specify the distance x. Then place the transducers at a distance equal to 2x on each side and measure t_1. Then connect the transducers at a distance equal to x from each side of the contract (according to Figure 5) and measure t_2. Now calculate the depth of the crack using the above relationship. (The unit of crack depth and x is the same.)

5.4 Estimation of compressive strength of concrete

In general, there are several methods for estimating the compressive strength of concrete using the pulse velocity in concrete, but the best method is the SonReb method, by means of destructive and non-destructive tests at the same time, and drew a diagram based on the results. In this method, each point in diagram, the ultrasonic pulse velocity , Schmidt hammer test and the compressive strength test is performed. This relationship is also applicable to only ultrasonic test results and compressive strength.

After obtaining the mentioned diagram (like Figure 6, which shows the relationship between pulse velocity and concrete compressive strength) and measuring the pulse velocity, it is possible to estimate concrete compressive strength.

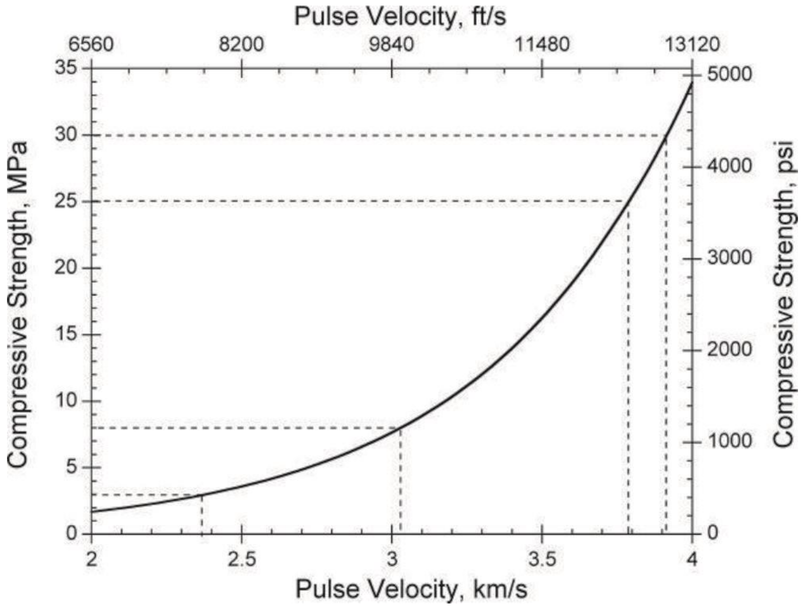


Figure 6-Compressive strength versus pulse velocity

6 Benefits

- It is cheap, fast and simple.
- It is well established in engineering communities.
- The test is non-destructive and does not damage the structure.
- It shows the quality of concrete (internal compressive strength).

7 Limitations

- Accessible surfaces are required.
- Good contacts between concrete surfaces and transducers are required.
- Some results are indirect and calculations are required.