CANTROL®

Construction Materials
Testing Equipment

Technical & Operations Manual
Ultrasonic Pulse Velocity Tester (UPV)



CANTROL®

August 2025

Disclaimer

This manual provides instructions for the operation and maintenance of the Cantrol's Ultrasonic Pulse Velocity Tester. The manufacturer is not liable for any damage or injury resulting from improper use, unauthorized modifications, or failure to adhere to the safety and operational guidelines outlined in this document. It is essential that the operator is fully trained and understands the principles of ultrasonic testing.

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1. Introduction

1.1 Purpose and Principle

The Ultrasonic Pulse Velocity (UPV) test is a non-destructive method used to assess the quality and integrity of materials, most commonly concrete. The method is based on measuring the travel time of an electronically generated ultrasonic pulse through a material. The pulse velocity is then calculated by dividing the path length by the travel time.

Higher pulse velocities generally indicate a material of good quality, with high density and uniformity. Lower velocities can suggest the presence of voids, cracks, honeycombing, or other internal defects.

1.2 Applications

The UPV tester is a versatile tool for:

- Assessing the general quality and homogeneity of concrete.
- Detecting internal flaws, cracks, voids, and delaminations.
- Evaluating the effectiveness of crack repairs.
- Monitoring changes in material properties over time (e.g., due to deterioration).
- Estimating the compressive strength of concrete (requires correlation with destructive tests).
- Determining the dynamic modulus of elasticity.

1.3 Referenced Standards

This equipment and the procedures outlined are designed to be in accordance with major international standards, including:

- **ASTM C597:** Standard Test Method for Pulse Velocity Through Concrete
- **EN 12504-4:** Testing concrete. Determination of ultrasonic pulse velocity
- **IS 13311 (Part 1):** Methods of Non-destructive testing of Concrete - Ultrasonic Pulse Velocity

2. Safety Precautions

WARNING: Read and understand this section completely before operating the instrument.

- **Electrical Safety:**
  - Only use the charger supplied by the manufacturer.
  - Do not operate the instrument in wet or explosive environments.
  - Ensure power cables are not damaged.
- **Equipment Handling:**
  - The instrument contains sensitive electronic components. Avoid dropping it or subjecting it to severe impact or vibration.
  - Do not attempt to open the device and transducers. There are no user-serviceable parts inside.
  - Keep the transducers and cables clean and in good condition.

3. Principle of Operation

The UPV system functions by generating a short-duration, high-frequency stress wave (an ultrasonic pulse) with a transmitting transducer. This pulse travels through the material being tested. A receiving transducer, placed at a known distance from the transmitter, detects the arrival of the pulse.

The instrument measures the transit time (T) for the pulse to travel the distance (L) between the two transducers. The pulse velocity (V) is then calculated using the fundamental formula:

V = L / T

Where:

- **V** is the Pulse Velocity (in km/s or m/s)
- **L** is the Path Length between transducers (in mm or m)
- **T** is the Transit Time (in microseconds, μs)

The velocity of the pulse is directly related to the elastic properties and density of the material. A dense, sound material will have a higher modulus of elasticity and will transmit the pulse at a higher velocity.

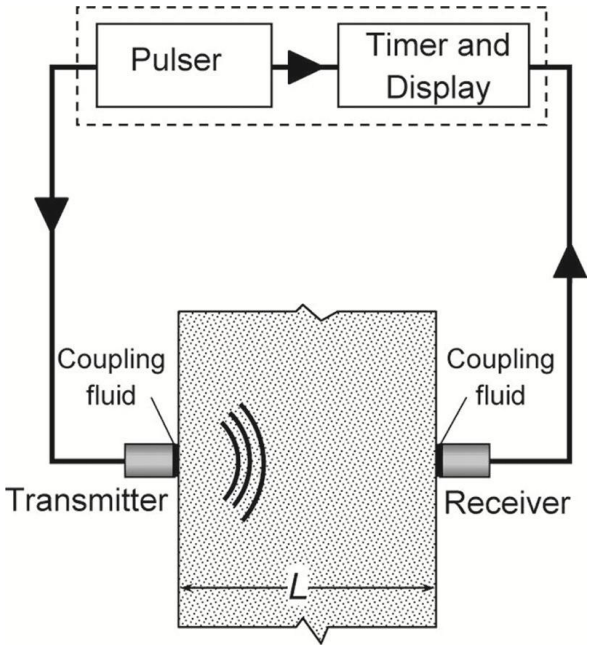


Figure 1- Schematic diagram of the device's operation

4. Apparatus Description

The UPV Tester consists of the following components:

1. **The Device:** The central processing unit of the system.
    - **Display:** A high-contrast LCD screen that shows transit time, velocity, exciting voltage and length.
    - **Keypad:** For navigating menus, entering data, and controlling test parameters.
    - **Transducer Sockets:** BNC connectors, outside for Transmitter and Receiver, inside for oscilloscope connection.
    - **USB Port:** For charging the internal battery.
2. **Transducers:**
    - **Transmitter and Receiver:** Transmitter converts an electrical signal from the device into a mechanical vibration (ultrasonic pulse). Receiver detects the ultrasonic pulse and converts it back into an electrical signal.

- **Frequency:** The standard set is 54 kHz, suitable for most concrete applications. Other frequencies (e.g., 24 kHz for long path lengths, 150 kHz for high resolution on thin sections) are available.

3. **Cables:** Coaxial cables with BNC connectors to link the transducers to the device.
4. **Calibration Rod:** A Plexiglas bar with a precisely known transit time labeled on it. Used for verifying the instrument's accuracy.
5. **Couplant:** A viscous material used to ensure good acoustic contact between the transducers and the test surface by eliminating air gaps.



Figure 2- The device and its accessories

5. System Setup and Calibration

5.1 Initial Setup

1. Connect the transmitter transducer to the socket on the device using one of the BNC cables.
2. Connect the receiver transducer to the socket.
3. Power on the instrument by pressing the ON/OFF button. The main menu will appear.

5.2 Check Calibration

This procedure nullifies the transit time through the transducer heads and cables and should be performed:

- Before the first use of the day.
- If the cables or transducers are changed.
- If the ambient temperature changes significantly.

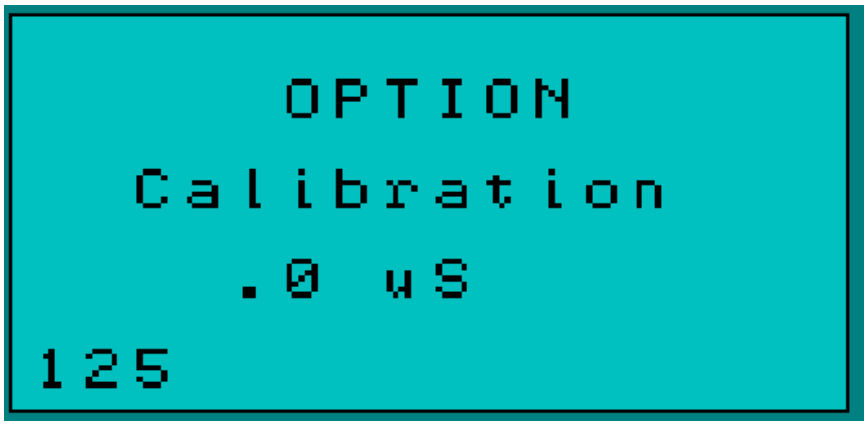
This procedure verifies the instrument is measuring time correctly.

1. Find the transit time value labeled on the calibration rod (e.g., 36.8 µs).
2. Apply a thin layer of couplant to both ends of the calibration rod and to the faces of the transducers.
3. Press the transducers firmly against the ends of the rod.
4. The transit time displayed on the screen should match the value labeled on the rod within the specified tolerance (e.g., ± 0.1 µs).
5. If the reading is out of tolerance, ensure good coupling and then calibrate the device.

5.3 Device calibration Procedure

1. When the device is stopped, go the settings menu by holding the start button.
2. Navigate to the 'Calibration' menu.
3. Apply a small amount of couplant to the faces of both transducers.

4. Press the faces of the two transducers firmly against the ends of the rod.
5. The display should read a transit time of calibration rod.
6. If not, use the up and down keys to select the travel time as indicated on the calibration rod. Then press stop.
7. The instrument is now calibrated.



6. Test Procedure

6.1 Surface Preparation

- Select test locations that are representative of the structure.
- The test surfaces must be clean and free of loose material, dust, and dirt.
- For very rough surfaces, it may be necessary to grind them smooth to ensure proper contact. A small patch of plaster or quick-setting mortar can also be used to create a smooth surface.

6.2 Application of Couplant

Apply a thin, consistent layer of couplant to the entire face of each transducer. This is a critical step; insufficient couplant will result in unstable readings or a total loss of signal.

6.3 Measurement Techniques

There are three primary methods for arranging the transducers:

a) Direct Transmission (Recommended)

- **Description:** Transducers are placed on opposite, parallel faces of the material.
- **Procedure:**
    1. Measure the path length (L) between the two points accurately.
    2. Press the transducers firmly onto the prepared surfaces directly opposite each other.
    3. Hold until the transit time reading (T) on the display is stable.
    4. Record the transit time and path length.
- **Advantage:** This method is the most reliable as the receiver detects the maximum pulse energy.

b) Semi-Direct Transmission

- **Description:** Transducers are placed on adjacent faces (i.e., around a corner).
- **Procedure:**
    1. Accurately measure the path length between the centers of the transducer faces.
    2. Press the transducers firmly onto the surfaces.
    3. Record the stable transit time.
- **Use:** When one of the opposite faces is inaccessible. The signal strength is weaker than in the direct method.

c) Indirect Transmission (Surface Probing)

- **Description:** Both transducers are placed on the same face, a known distance apart.
- **Procedure:**
    1. Mark a line and place the receiver at a fixed position.
    2. Place the transmitter at increasing distances from the receiver (e.g., 100mm, 150mm, 200mm, etc.) along the line.
    3. Record the transit time for each distance. Plot a graph of path length vs. transit time. The slope of the line gives the pulse velocity.

- **Limitation:** This method is the least sensitive and is heavily influenced by the surface layer of the concrete, which may not be representative of the core. It is typically used for crack depth estimation.

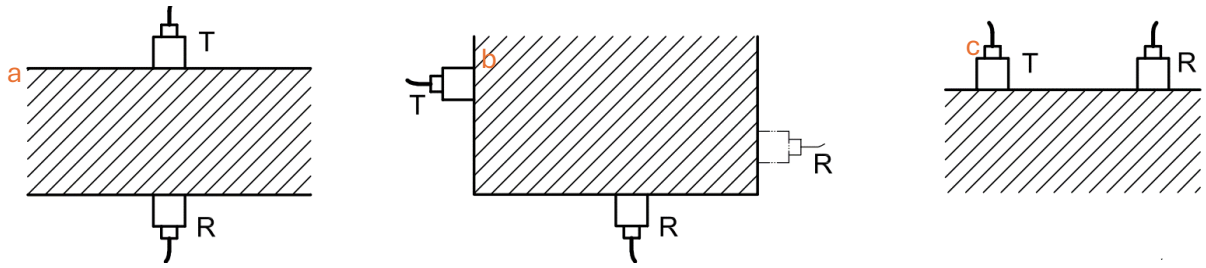
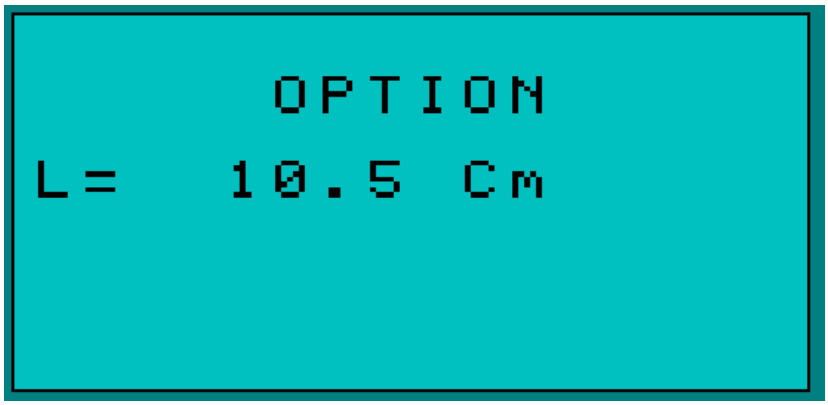
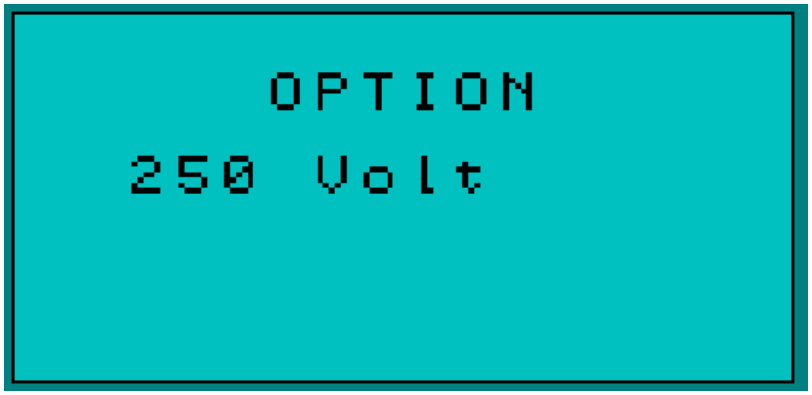


Figure 3- transducers arrangements: (a) direct (b) semi-direct (c) indirect

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.



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



7. Data Interpretation

7.1 Calculating Pulse Velocity

Use the recorded path length (L) and transit time (T) to calculate the velocity: **V (km/s) = L (mm) / T (µs)** or **V (m/s) = L (m) / T (s)**

7.2 Factors Affecting Pulse Velocity

- **Moisture Content:** Saturated concrete can yield velocities up to 5% higher than dry concrete.
- **Reinforcement:** Steel has a much higher pulse velocity (~5.9 km/s) than concrete. Measurements taken along the axis of a reinforcing bar will yield artificially high velocities. Tests should be conducted perpendicular to the main reinforcement where possible.
- **Temperature:** Velocity increases as temperature decreases and vice-versa.
- **Concrete Properties:** Aggregate type, cement type, and mix proportions all influence the final velocity.

7.3 Concrete Quality Classification

The following table provides a general guide for assessing concrete quality based on direct transmission UPV results. (Note: These values can vary based on mix design and local standards).

Pulse Velocity (km/s)	Concrete Quality Classification
> 4.5	Excellent
3.5 - 4.5	Good
3.0 - 3.5	Medium / Questionable
< 3.0	Poor / Doubtful
< 2.0	Very Poor

7.4 Flaw Detection

A grid of readings taken over an area can be used to map its uniformity. A significant drop in velocity (e.g., 10-15% or more) in a specific location compared to surrounding areas is a strong indicator of a potential defect like a void or crack.

7.5 Estimation of surface crack depth

Use the following equation to measure the crack depth:

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

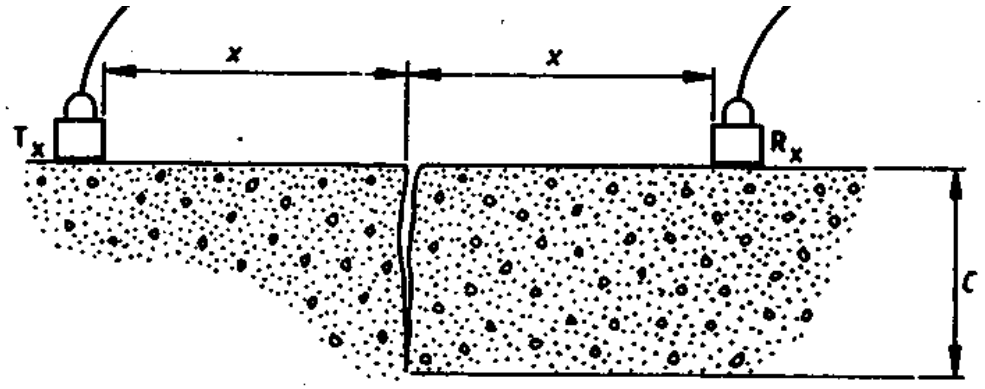


Figure 4- Crack depth calculation

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.)

7.6 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.

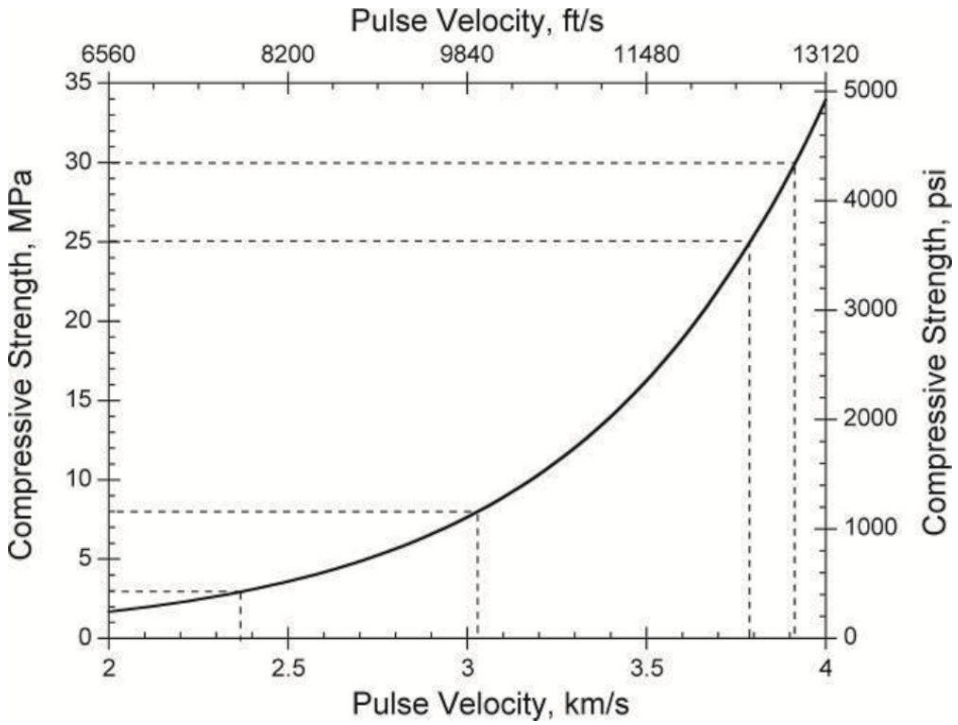


Figure 5-Compressive strength versus pulse velocity

8. Maintenance and Troubleshooting

Problem	Possible Cause(s)	Solution(s)
No reading or unstable reading	1. Lack of couplant or poor contact. 2. Very poor quality or cracked material. 3. Damaged cable or transducer. 4. Path length too long for frequency.	1. Re-apply couplant and press firmly. 2. Try a different test location. 3. Check cables; try swapping them. Test with calibration rod. 4. Use lower frequency transducers.
Reading is obviously wrong	1. Incorrect path length entered. 2. Instrument not calibrated correctly. 3. Measurement along rebar.	1. Re-measure the path length accurately. 2. Perform the calibration procedure. 3. Change the test location to avoid direct influence of steel.
Instrument does not power on	1. Battery is fully discharged. 2. Faulty charger or internal fault.	1. Charge the instrument for at least 4 hours. 2. Try a different charger if available. Contact service center.

Care and Storage:

- After use, clean the transducers and cables with a damp cloth to remove all couplant.
- Store the instrument and all accessories in the provided carrying case.
- Store in a clean, dry place away from extreme temperatures.
- Charge the battery regularly, even when not in use, to maintain its health.

9. Technical Specifications

Parameter	Specification
Measurement Range	0.1 µs to 2000 µs
Resolution	0.1 µs
Accuracy	± 0.1 µs
Operating Voltage	50V to 500V (Selectable)
Transducer Frequency	54 kHz (Standard); 24 kHz to 250 kHz (Optional)
Operating Temperature	0°C to 50°C (32°F to 122°F)
Power Supply	Internal rechargeable Li-Ion battery
Battery Life	> 10 hours continuous operation
Outputs	connection to an oscilloscope