Pulsar

Purpose

Pulsar (A1410) is a compact, hand-held, coupling-free instrument for measuring the speed of a pulse of ultrasonic longitudinal stress waves propagating within concrete; that is, it measures the ultrasonic pulse velocity (UPV).

The instrument incorporates two antenna arrays, each one with a set of 7 dry-point-contact (DPC) transducers that are brought into contact with the surface of the test object. The receiving antenna is fixed to the electronic unit while the transmitting antenna is connected by a 3 meter cable.

Pulsar can be used for the following applications:

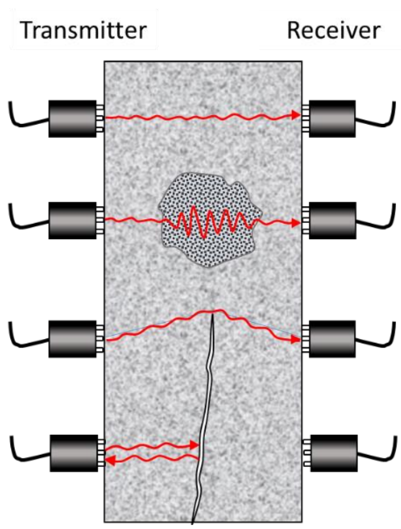
- Assessment of concrete uniformity
- Locating internal voids and cracks
- Estimation of the extent and severity of deterioration
- Estimating depth of fire damaged concrete
- Evaluation of damage to test specimens during durability testing (freeze and thaw, sulfate attack, alkali-silica reaction)
- Estimation of depth of surface-opening cracks
- Estimation of early-age strength (with project/mixture specific correlation)
- Evaluation of condition or elastic properties of solid materials like rocks, bricks or composites.

Principle

A pulse of ultrasonic longitudinal stress waves is introduced into one surface of a concrete member by the transmitting antenna. The pulse travels through the concrete, is received by a similar antenna on a different surface and its transit time is determined by the instrument. If the distance between the transducers is divided by the transit time, the pulse velocity can be obtained. The longitudinal pulse velocity, C_p, of an elastic solid is a function of the elastic constants (modulus of elasticity, E, and Poisson's ratio, ν) and the density, ρ.

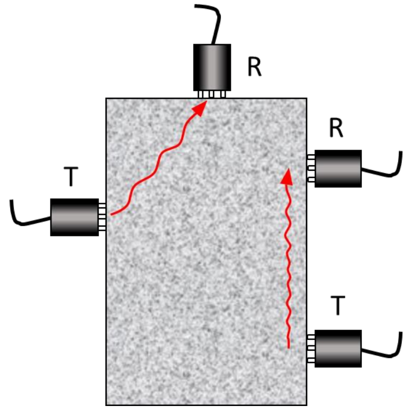
$$C_p = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}}$$

In contrast with traditional pulse velocity instruments, the antennas are built with dry-point-contact (DPC) transducers in order to work without a coupling material (grease or gel). These transducers allow to make measurements much quicker.



The figure to the right illustrates examples of different conditions that may be encountered when testing an element. At the top, the path between the transducers is through solid concrete, and the travel time would be the shortest. Below that is the case where there is an internal pocket of porous concrete, such as honeycombed concrete. The pulse is scattered as it travels though the contiguous portions of the honeycombed concrete. As a result, the travel path is longer and the pulse travel time is longer as well. This results in a reduced pulse velocity. In the next case, the transducers are located so that the direct travel path is near the edge of a crack. The pulse cannot travel across a concrete-air interface, but it is able to travel from the transmitter to the receiver by diffraction at the crack edge. Because the travel path is longer than the distance between the transducers, the apparent pulse velocity is lower than through sound concrete. In the lowermost case, the pulse is reflected completely by the crack, and travel time is not measurable.

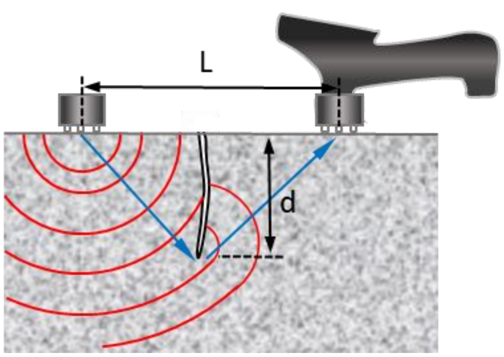
These examples correspond to the direct thru-transmission method where the transducers are positioned in opposite parallel faces of the concrete element. There are however cases where access to the opposite side of the element is restricted. The semi-direct and indirect transmission methods are alternatives in such situations although surface conditions of the concrete or the presence of steel reinforcement might interfere in the measurements. The relevant standards and guidelines for Ultrasonic Pulse Velocity testing give advice on what aspects the user have to take care of if these techniques are to be used.



The UPV test method is governed by various standards including ASTM C597, BS 1881:203, and EN 12504-4. The method is totally nondestructive and it is possible to repeat the test at the same point at different times to determine changes of UPV with time. It is also highly repeatable. For tests of sound concrete, the coefficient of variation for repeated measurements at the same location is 2 %. The accuracy of the pulse velocity is a direct function of the accuracy of the measured distance between the transducer faces.

Crack depth estimation

Pulsar can also be used to estimate the depths of surface-opening cracks. When the stress pulse reaches the tip of a surface-opening crack, the pulse is diffracted by the crack tip. The diffracted pulse travels away from the crack tip and is detected by the receiver. Because the crack increases the length of the travel path from transmitter to receiver, the transmit time will be greater than if no crack were present. Crack depth is determined by making two transit time measurements. The first one is made with the transducers aligned parallel to the crack, and the second one is made with the transducers perpendicular to the crack (figure below). For the second measurement, the crack should be at the midpoint between the transducers. By using these transit times and the distance between the transducers, the crack depth can be calculated:



$$d = \frac{L}{2}\sqrt{\left(\frac{t_c}{t_p}\right)^2 - 1}$$

Where L is the distance between the transducers, t_p is the transit time measured with the transducers parallel to the crack, and t_c is the transit time with transducers perpendicular to the crack.

Estimating In-place Strength

To use **Surfer** to estimate early-age strength development of concrete, a relationship needs to be established between concrete strength and pulse velocity. Such a relationship can be established by making pulse velocity measurements on standard strength test specimens and then measuring their compressive strength. The resulting data can be used to develop a regression equation to represent the relationship between concrete strength and pulse velocity. Refer to ACI 228.1R (In-Place Methods to Estimate Concrete Strength) for guidance on developing and using the strength relationship. The relationship that is developed is applicable only to that specific concrete mixture.

Elastic Modulus Degradation

Because the modulus of elasticity is proportional to the square of the pulse velocity, **Pulsar** can be used as an alternative to resonant frequency testing to monitor deterioration of specimens used in standard durability tests, such as freezing and thawing. In such tests, the decrease in the dynamic modulus of elasticity is used as an indicator of deterioration. The elastic modulus ratio is equal to the square of the pulse velocity ratio:

$$\frac{E_n}{E_i} = \left(\frac{V_n}{V_i}\right)^2$$

Where V_i and E_i are the initial values of pulse velocity and modulus of elasticity; and V_n and E_n are the values of pulse velocity and modulus of elasticity after exposure to the test conditions.

Pulsar Specifications

- Antennas with an array of 7 dry point contact, undamped, longitudinal-wave transducers
- The signal waveform can be displayed
- Operating frequency: 50 kHz
- Rechargeable battery with 16 hours life
- 2.8”, 320 × 240 LCD screen
- Data transfer to computer via USB
- Transit time measurement range: 0.1 to 10,000 μs
- Pulse velocity measurement range: 1,000 to 15,000 m/s
- Transit time (t) measurement accuracy: ± (0.02·t + 0.1) μs
- Resolution: 0.1 μs (transit time), 10 m/s (pulse velocity)
- Maximum distance to measure: 2,500 mm
- Automatic Gain Control (AGC) function.
- Storage capacity: 50,000 results
- Metric and inch-pound units
- Instrument’s weight: 420 g
- Instrument’s dimensions: 230 x 125 x 65 mm
- Operating conditions: Temperature: -10 to 50 °C, RH ≤ 95 %

Pulsar (PUL-1000) Ordering Numbers

tem	Order #
Hand-held electronic unit, Pulsar A1410, with carrying case	PUL-1001
Transmitter antenna array with 7 DPC transducers, longitudinal wave	PUL-1002
LEMO-LEMO cable, 3 m	PUL-1003
Charger and USB cable for connection to PC	PUL-1004
Reference specimen with calibration certificate	PUL-1005
User manual	PUL-1006