JENSEN HUGHES

Advancing the Science of Safety

NONDESTRUCTIVE TESTING – CONCRETE STRENGTH

Zoom with Tennessee Concrete Association

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- Pre-Bid/Pre-Construction Consulting
- Construction Troubleshooting Consulting
- Existing Structures & Post Construction
- Product Development R&D Consulting

NONDESTRUCTIVE TESTING – CONCRETE STRENGTH

ACI Certification of Nondestructive Testing Specialist

- 90 minute ACI Written Exam
  - Closed book with 70 multiple choice questions.
  - About 7-8 questions per test method and practice
  - At least 60% correct for each of the required test methods and practices; AND
  - Minimum 70% score overall
- Performance Exam
  - Closed book
  - Requires actual demonstration of four of the required test methods and practices
  - Judged on his/her ability to correctly perform (or describe, where allowed) all the required steps for each procedure
- Certification is valid for five years; recertification at the end of that term requires successful completion of both the written and performance exams

NONDESTRUCTIVE TESTING – CONCRETE STRENGTH

ACI Certification of Nondestructive Testing Specialist

+ ASTM C805, Rebound Number of Hardened Concrete
+ ASTM C803, Penetration Resistance of Hardened Concrete
+ ASTM C597, Pulse Velocity Through Concrete
+ ASTM C900, Pullout Strength of Hardened Concrete
+ ASTM C873, Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
+ ASTM C1074, Estimated Concrete Strength by the Maturity Method

+ Understand
  - Scope of test method
  - Significance and use
  - Procedure and equipment
  - Limitations

ASTM C805 – Rebound Number of Hardened Concrete

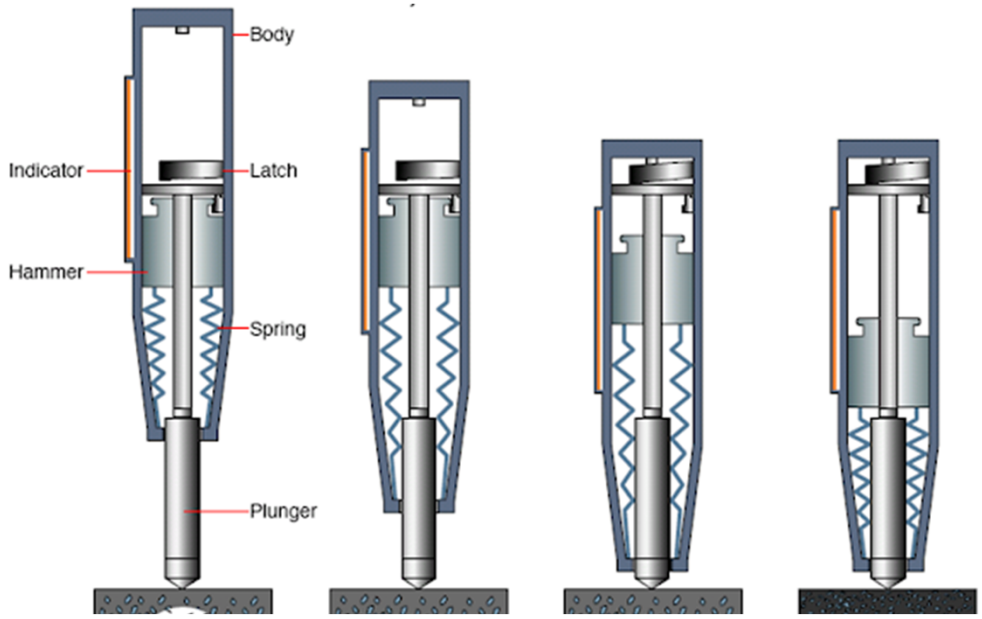
History and Significance

+ Invented by Swiss engineer, Ernst Schmidt
+ Applicable to assess the in-place uniformity of concrete
+ Can be used to estimate in-place strength *if* a correlation is developed.
+ Can be used to assess the quality of the concrete

ASTM C805 – Rebound Number of Hardened Concrete

Principle

+ Based on the principle that the rebound of an elastic mass depends on the hardness of the concrete.



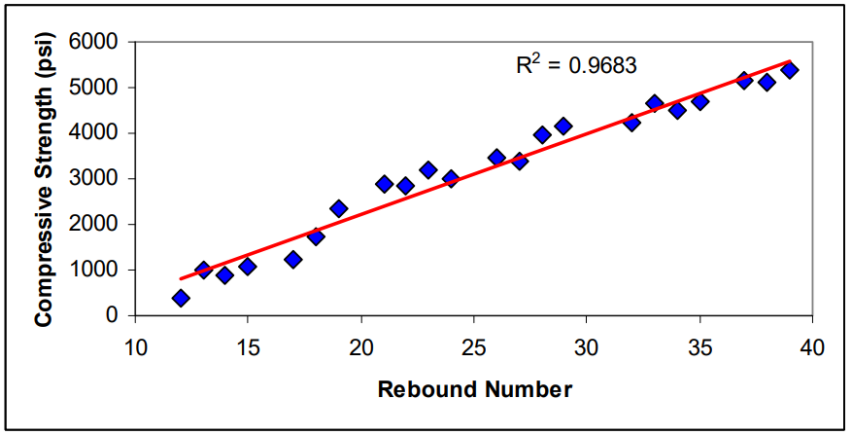
https://www.engineersdaily.com/2011/04/rebound-hammer-test.html

ASTM C805 – Rebound Number of Hardened Concrete

Procedure

- Calibrate
- Determine relationship
  - Correlate rebound numbers measured on the structure with measured strengths of cores taken from same area.
  - ACI 228.1R has additional information on developing correlation
- Select Test Surface
  - at least 4” thick and fixed.
  - 6” in diameter
  - Avoid areas of honeycombing, scaling, high porosity

Verification anvil sold by Gilson



ASTM C805 – Rebound Number of Hardened Concrete

- Prepare Test Surface
  - Free surface of loose mortar
  - Remove surface water
- Do not test frozen concrete
- Do not conduct tests directly over reinforcing bars with cover less than ¾”
- Take measurements
  - Be perpendicular to the surface
  - Take ten readings from each test area.
  - Distances between impact points shall be at least 1 inch.
  - Distance between impact points and edges should be least 2 inches.
  - Examine the impression made on the surface after impact. If the impact crushes or breaks through a near-surface void, disregard the reading.

ASTM C805 – Rebound Number of Hardened Concrete

Data Interpretation

Quality of Concrete	Average Rebound Number
Very good hard layer	More than 40
Good layer	30 to 40
Fair	20 to 30
Poor Concrete	Less than 20
Delaminated	0

ASTM C805 – Rebound Number of Hardened Concrete

Pros and Cons

+ Pros
  - Easy to use
  - Fast
  - Relatively inexpensive
+ Cons
  - Results obtained is based on a local point (surface)
  - Wide range of variability
  - Results are not directly related to the strength and deformation property of the surface
  - Flaws cannot be detected with accuracy
  - Can leave surface damage

ASTM C805 – Rebound Number of Hardened Concrete

Factors Influencing Rebound Numbers

- Type of Aggregate
- Surface condition
- Moisture condition
- Curing and Age of concrete
- Carbonation of concrete surface

ASTM C803 – Penetration Resistance of Hardened Concrete

History and Significance

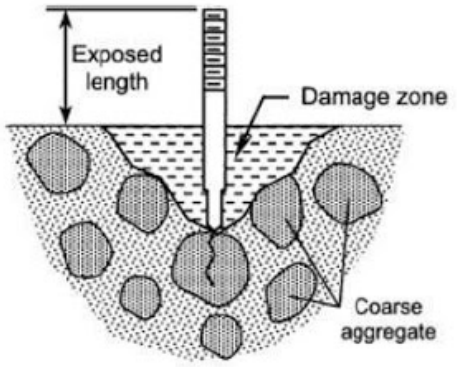
- Developed by New York Port Authority and the Windsor Machine Company
- Based on the surface hardness to estimate concrete strength
- Applicable to assess the in-place uniformity of concrete
- Can be used to estimate in-place strength *if* a correlation is developed.
- Can be used to assess the quality of the concrete

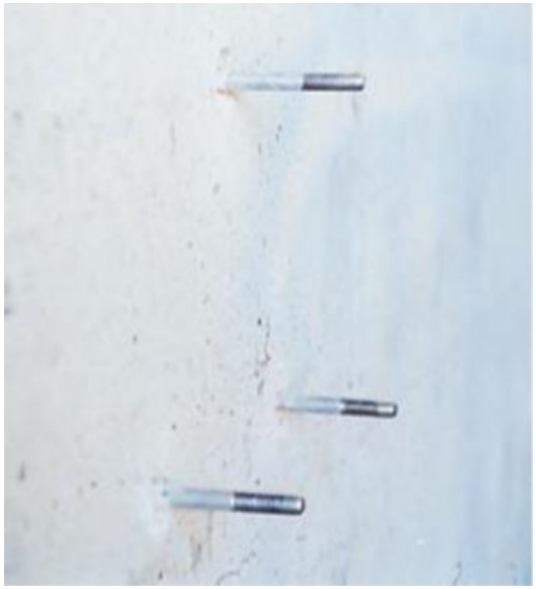
Windsor Probe

ASTM C803 – Penetration Resistance of Hardened Concrete

Principle

+ Based on the principle that the exposed lengths of probes or depth of penetration of the pins into the concrete is related to the compressive strength of concrete





ASTM C803 – Penetration Resistance of Hardened Concrete

Sampling – Resistance Testing with Probes

+ Concrete must have reached sufficient degree of resistance to penetration so that the probe will not penetrate more than one half the thickness of the concrete member
+ > 7 inches from other probes
+ > 4 inches from the edge
+ Minimum three probes in a test area is one test

Sampling – Resistance Testing with Pins

+ Concrete must have reached sufficient degree of resistance to penetration so that the pin does not penetrate to a depth greater than the exposed length of the pin.
+ 2-6 inches from other pins
+ > 2 inches from the edge
+ Minimum six pins in a test area is one test

ASTM C803 – Penetration Resistance of Hardened Concrete

Procedure – Resistance Testing with Probes

- Prep the surface
- Place the positioning device on the test location
- Mount the probe in the driver unit, position the driver in the positioning device
- Fire the probe into the concrete.

ASTM C803 – Penetration Resistance of Hardened Concrete

Procedure – Resistance Testing with Probes

- Remove the positioning device, and tap the probe on the exposed end with a small hammer to ensure that it is firmly embedded. Reject any loose probes.
- Place the reference base plate over the probe, and make sure it is flat.
- Measure the distance from the reference base plate to the end of the probe.
- Discard any probes that are more than 10 degrees out of perpendicularity.
- For lightweight concrete, decrease the amount of energy delivered to the probe or use larger diameter probes.

ASTM C803 – Penetration Resistance of Hardened Concrete

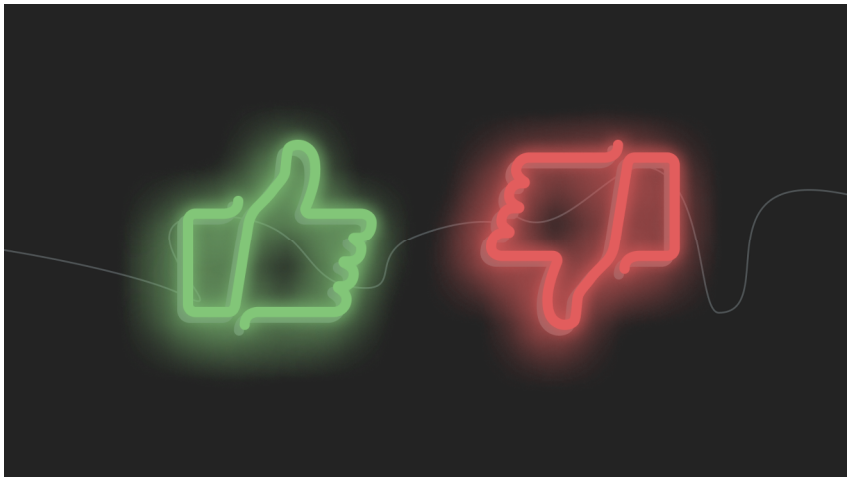
Procedure – Resistance Testing with Pins

- Prep the surface
- Surface should be flat with no visible gap between the surface and a pin laid sideways on the surface.
- Insert a new pin into the spring-actuated driver unit, load the driver, place the driver unit firmly against the perpendicular surface.
- Pull the trigger to release the spring and drive the pin into the concrete surface.
- Remove the unit including the pin
- Clean the pin hole using the air blower device
- Insert depth gage into the pin hole and measure the depth of penetration.

ASTM C803 – Penetration Resistance of Hardened Concrete

Pros and Cons

+ Pros
  - Easy to use
  - Fast
  - Relatively inexpensive
+ Cons
  - Results obtained is based on a local point (surface)
  - Not completely nondestructive



ASTM C803 – Penetration Resistance of Hardened Concrete

Factors Influencing Penetration Resistance

+ Type, size, and distribution of aggregates
+ Location of embedded reinforcing steel
+ Carbonation of concrete surface
+ Surface finish (wood form finish vs steel form finish).

ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

History and Significance

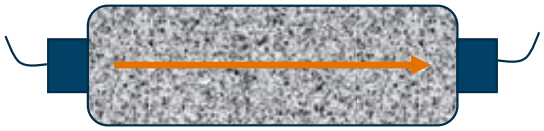
- 1920, Sergei Y. Sokolov first proposed the use of UPV to find defects in metal objects
- 1942, Progress made by Firestone at the University of Michigan with improvements with the instrumentation
- 1970s, fracture mechanics and development of new laws to predict growth rate of cracks in concrete under cyclic loading
- Applicability to concrete:
  - Assess uniformity, relative quality, verify thickness
  - Indicate presence of voids and cracks
  - Effectiveness of crack repairs
  - Indicate changes in concrete
  - Estimate severity of deterioration

ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

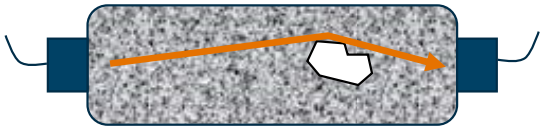
Principle

- Measures speed of soundwaves
- Generally, slower soundwaves correlate with low quality concrete that has defects and anomalies, and faster soundwaves correlate with high quality concrete that has few anomalies.

$$Velocity = {}^{Length}/_{Transit\ Time}$$



High Quality Concrete



Low Quality Concrete

- The pulse velocity, V, of longitudinal stress waves in a concrete mass is related to its elastic properties and density according to the following relationship:

$$V = \sqrt{\frac{E\ (1-\mu)}{\rho(1+\mu)(1-2\mu)}}$$

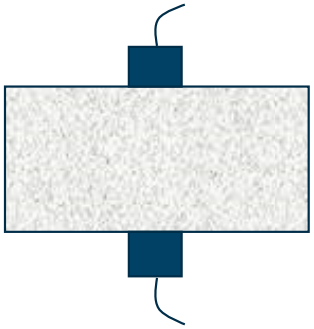
ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

Procedure

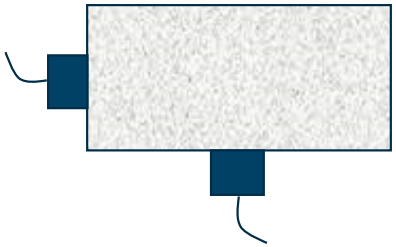
- Functional Check of Equipment and Zero-time Adjustment
- Plan your measurement locations.
  - For existing construction follow ASTM C823, *Standard Practice for Examination and Sampling of Hardened Concrete in Constructions*
- Use a coupling agent (water, oil, petroleum jelly, grease, moldable rubber, other viscous material)
- For best results, locate the transducers directly opposite of each other.

ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

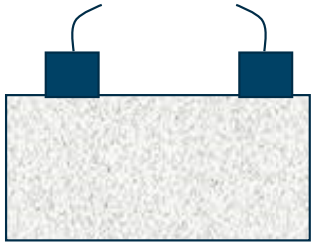
Procedure



direct



semi-direct



indirect
(surface)

+ Direct – most accurate configuration, mainly used to test lab samples and concrete cores
+ Semi-direct – less accurate, used when top and side element are accessible
+ Indirect – least satisfactory and used when only one surface is accessible. Indicates quality of the concrete near the surface.

ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

Data Interpretation

Quality of Concrete	Velocity (m/s)
Excellent	> 4,500
Good	3,500 – 4,500
Mediocre/Fair	3,000 – 3,500
Poor	2,000 – 3,000
Very Poor	<2,000

ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

Pros and Cons

+ Pros
  - Completely nondestructive
  - Reliable measure of the change in concrete
  - More consistent than rebound hammer and penetration resistance
+ Cons
  - A high degree of operator skill and integrity is needed; requires training and certification
  - Variability
  - Materials like steel can affect results

ASTM C597 – Ultrasonic Pulse Velocity Through Concrete

Factors Influencing UPV

+ Type, size, and distribution of aggregates
+ Quality of testing surface and transducer contacts
+ Degree of hydration, concrete age
+ Degree of saturation
+ Presence of reinforcement.

NONDESTRUCTIVE TESTING – CONCRETE STRENGTH

Summary

+ ASTM C805, Rebound Number of Hardened Concrete
+ ASTM C803, Penetration Resistance of Hardened Concrete
+ ASTM C597, Pulse Velocity Through Concrete
  - Scope of test method
  - Significance and use
  - Procedure and equipment
  - Limitations

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Questions?

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