Testing for In-Place Strength

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Outline

- Background
- Review of three methods for in-place strength
  - Rebound hammer
  - Probe penetration
  - Pullout test
- Statistical considerations
- Summary

Performance-Based Requirements

- Owner is interested in results; less interested in how results are obtained
- Owner specifies
  - Required quality characteristics
  - Methods for sampling and testing
  - Acceptance criteria

Current Practice

- Testing of standard-cured specimens
  - Sampling at point of delivery (discharge)
  - Establishes if concrete as delivered meets contractual requirements
  - In-place performance is not assessed
- Testing of field-cured specimens (ACI 318-08, 5.6.4)
  - Assess adequacy of curing
  - When required by Engineer or Building Official

Future Practice

- Testing of standard-cured specimens
  - Still required for contractual agreement with concrete supplier
- Testing for in-place properties
  - Assurance that concrete in structure meets Owner's requirements
    - Strength for structural safety ⟵
    - Durability-related properties for service life

Field-Cured Specimens
(ASTM C31/C31 M)

- Stored under "same" conditions as structure
- Problems:
  - Consolidation not representative of concrete in structure
  - Temperature history not same as concrete in structure (mass/area effect)
  - Can't evaluate strength at critical locations
  - Specimens are prone to mishandling and abuse
  - Specimens must be sent to laboratory

Alternative is in-place tests.

In-Place Tests

Advantages

- Measure properties of concrete in structure
- Concentrate on critical portions of structure
- Inexpensive compared with coring

Disadvantages

- Indirect measure of compressive strength
- Require correlation (strength relationship)
- Planning and interpretation

References

ACI 228.1R-03

In-Place Methods to Estimate Concrete Strength

Reported by ACI Committee 228

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P.O. BOX 9094
FARMINGTON HILLS, MICHIGAN 48333-9094

Designation: C 805/C 805M – 08

Standard Test Method for Rebound Number of Hardened Concrete[1]

Designation: C 803/C 803M – 03

Standard Test Method for Penetration Resistance of Hardened Concrete[1]

Designation: C 900 – 06

Standard Test Method for Pullout Strength of Hardened Concrete[1]

This standard is issued under the fixed designation C 900; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers determination of the pullout strength of hardened concrete by measuring the force required to pull an embedded metal insert and the attached concrete fragment from a concrete test specimen or structure. The insert is either cast into fresh concrete or installed in hardened concrete. This test method does not provide statistical procedures to estimate other strength properties.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (WARNING—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E 4 Practices for Force Verification of Testing Machines

E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

3. Summary of Test Method

3.1 A metal insert is either cast into fresh concrete or installed into hardened concrete. When an estimate of the in-place strength is desired, the insert is pulled by means of a jack reacting against a bearing ring. The pullout strength is determined by measuring the maximum force required to pull the insert from the concrete mass. Alternatively, the insert is loaded to a specified load to verify whether a minimum level of in-place strength has been attained.

4. Significance and Use

4.1 For a given concrete and a given test apparatus, pullout strengths can be related to compressive strength test results. Such strength relationships depend on the configuration of the embedded insert, bearing ring dimensions, depth of embedment, and level of strength development in that concrete. Prior to use, these relationships must be established for each system and each new combination of concreting materials. Such relationships tend to be less variable where both pullout test specimens and compressive strength test specimens are of similar size, compacted to similar density, and cured under similar conditions.

NOTE 1—Published reports (1-17)[4] by different researchers present their experiences in the use of pullout test equipment. Refer to ACI 228.1R (14) for guidance on establishing a strength relationship and interpreting test results. The Appendix provides a means for comparing pullout strengths obtained using different configurations.

4.2 Pullout tests are used to determine whether the in-place strength of concrete has reached a specified level so that, for example:

(1) post-tensioning may proceed;

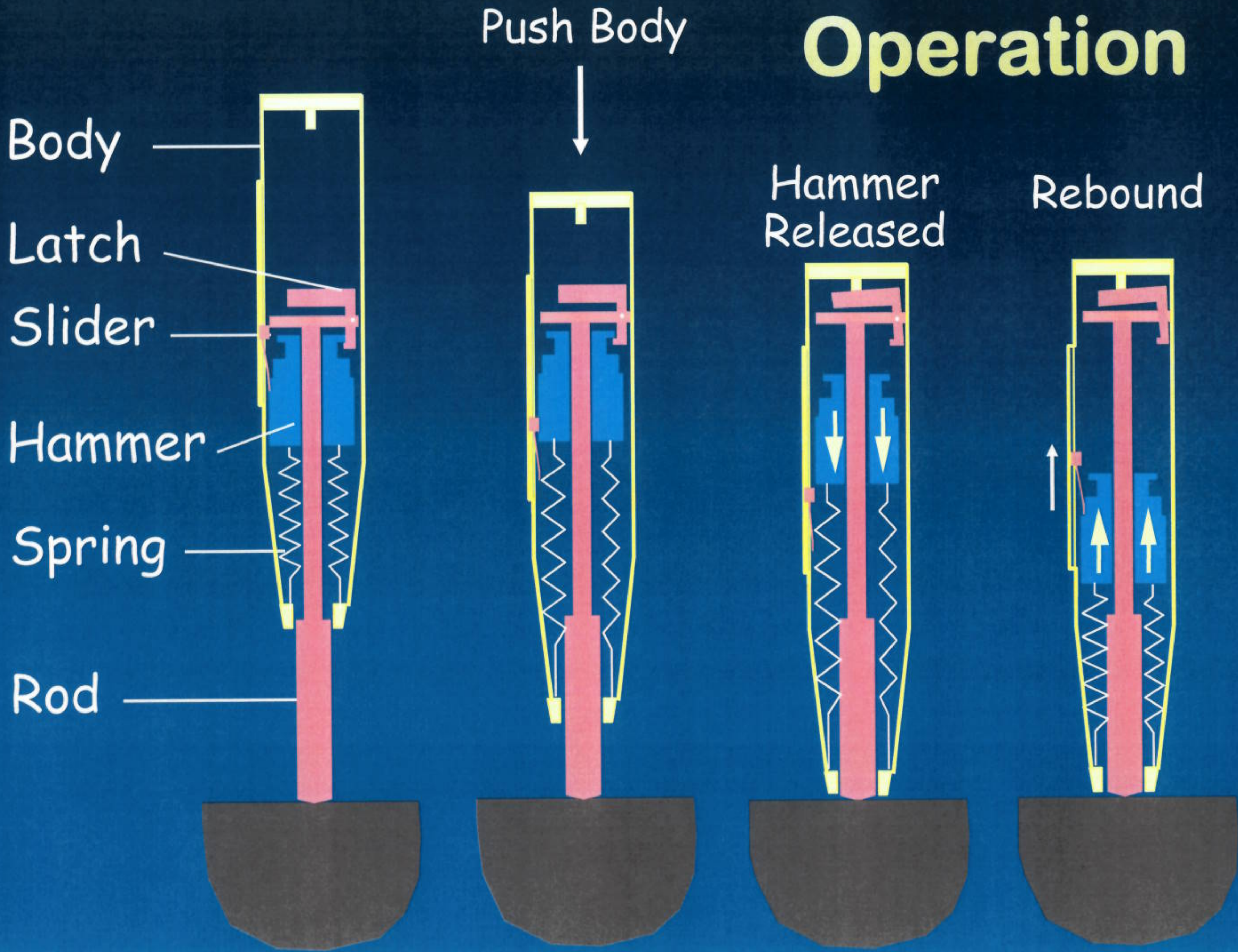
In-Place Test Methods

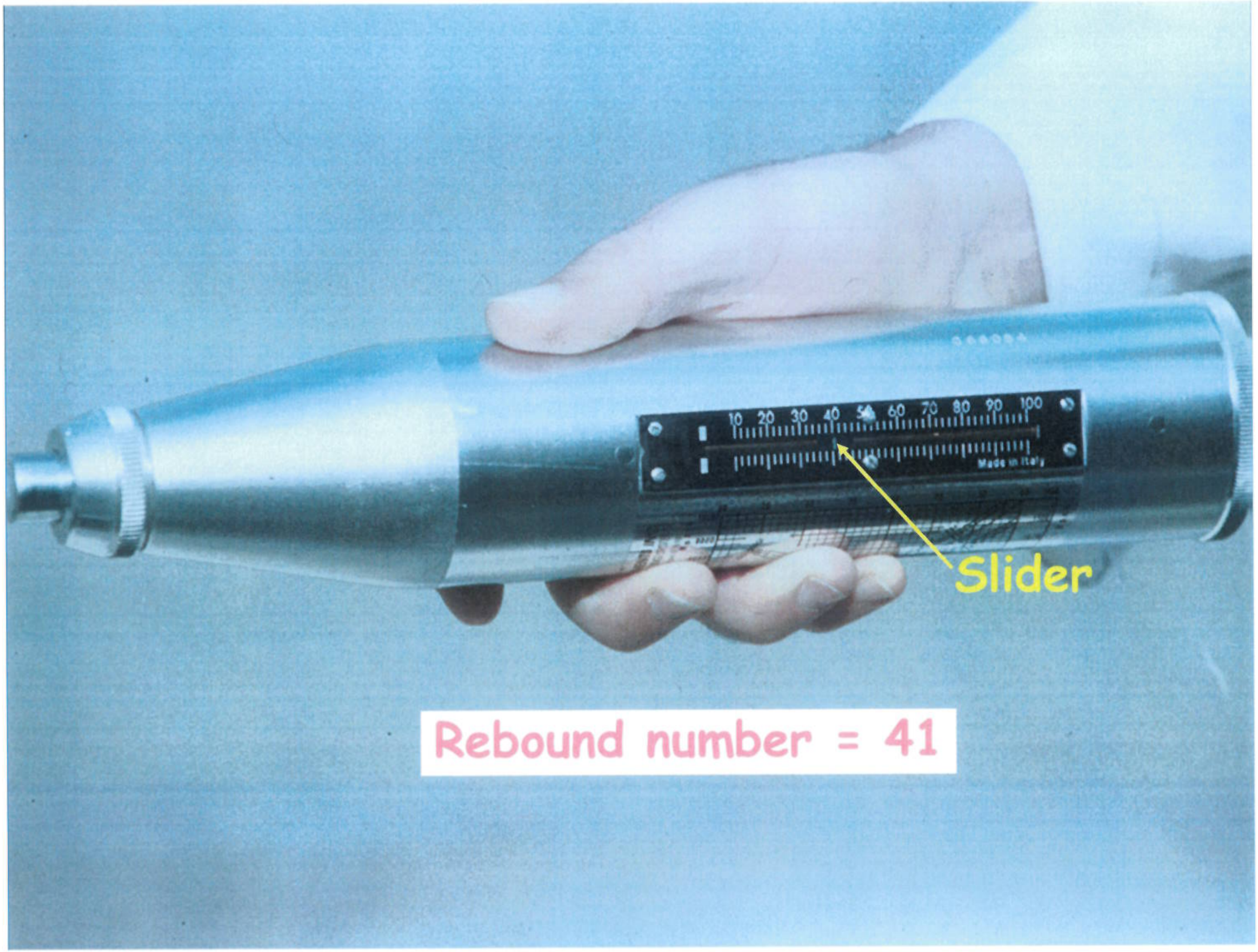
- Rebound number—ASTM C805/C805M
- Probe penetration—ASTM C803/C803M
- Pullout test—ASTM C900

ASTM C805/C805M Rebound Number of Hardened Concrete

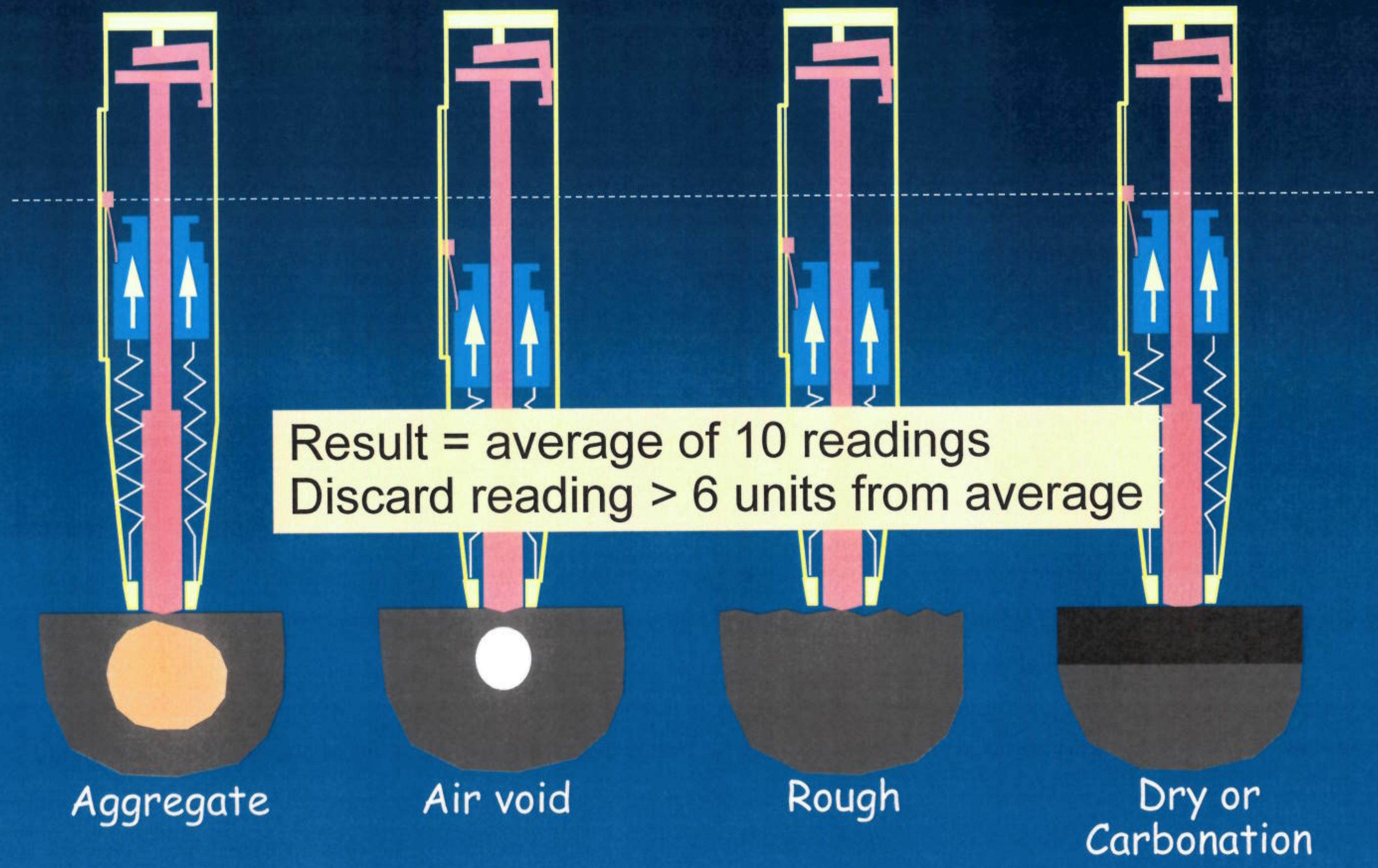
- Measure the rebound of spring-driven mass (hammer) after impact with rod in contact with concrete.

Operation


Push Body
Body
Latch
Slider
Hammer
Spring
Rod
Hammer Released
Rebound


10 20 30 40 50 60 70 80 90 100
Made in Italy
Slider
Rebound number = 41

Near-surface Effects



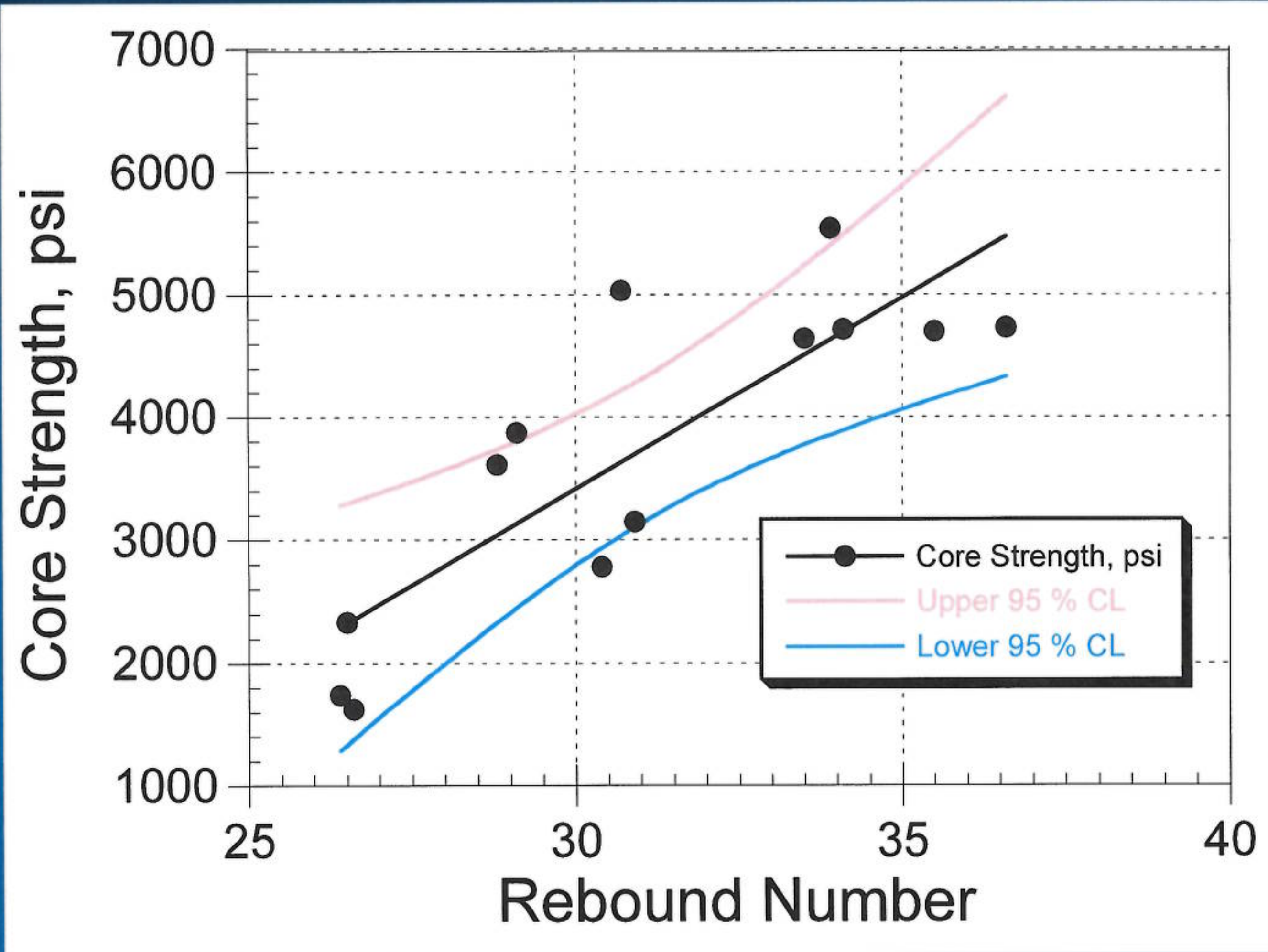
Correlation Testing
ACI 228.1R Chapter 4

- Alternative 1
  - Cast cylinders
  - At regular strength intervals (≥ 6)
    - Support cylinders in testing machine and measure rebound number
    - Test cylinders in compression
- Alternative 2
  - Measure rebound on structure
  - Drill and test cores

ASTM C 805/C805-08

- Alternative 2 is recognized
  - Accounts for surface conditions
    - Texture
    - Moisture condition
  - Accounts for hammer orientation
- "5.5 This test method is not suitable as the basis for acceptance or rejection of concrete."

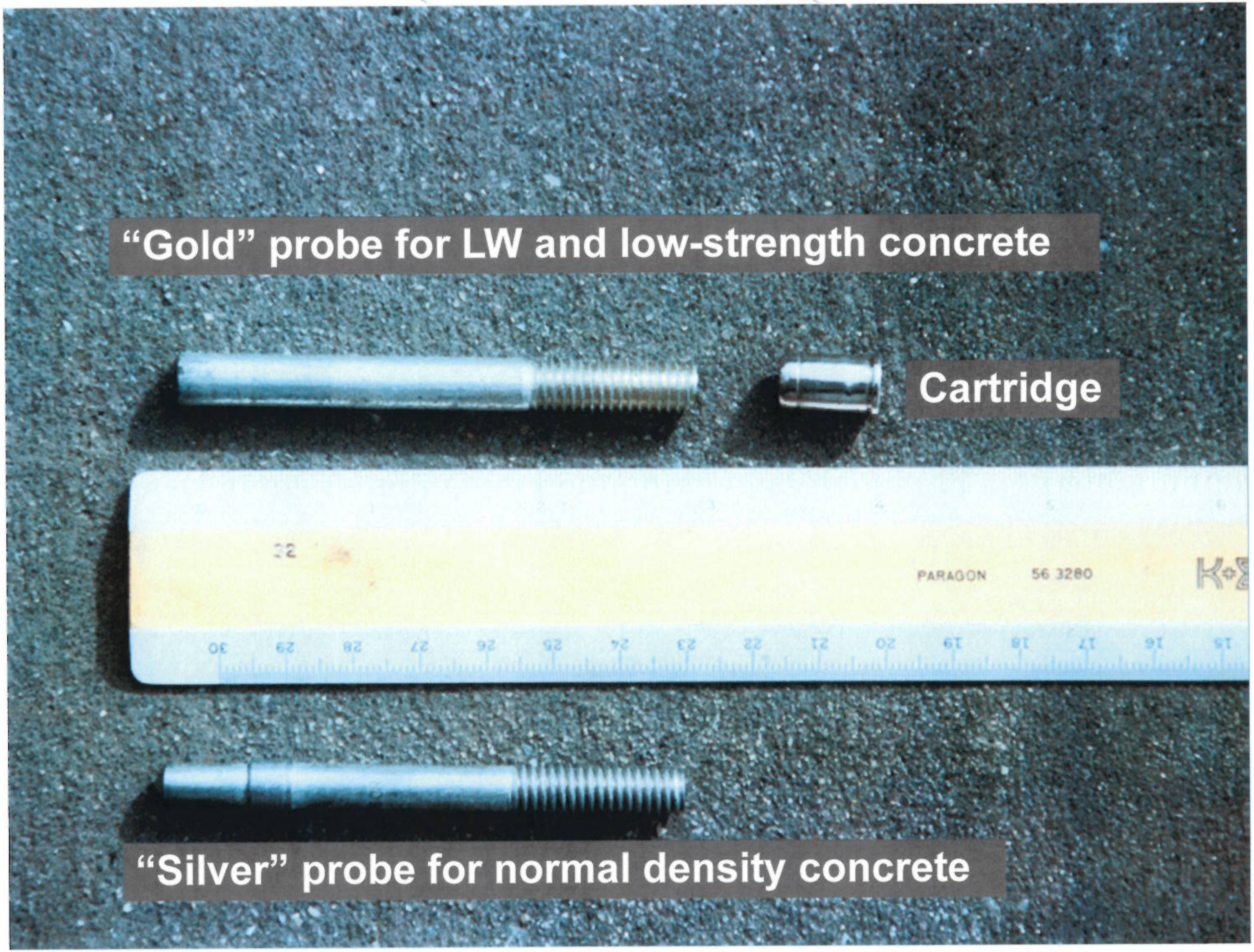
Example of Strength Relationship

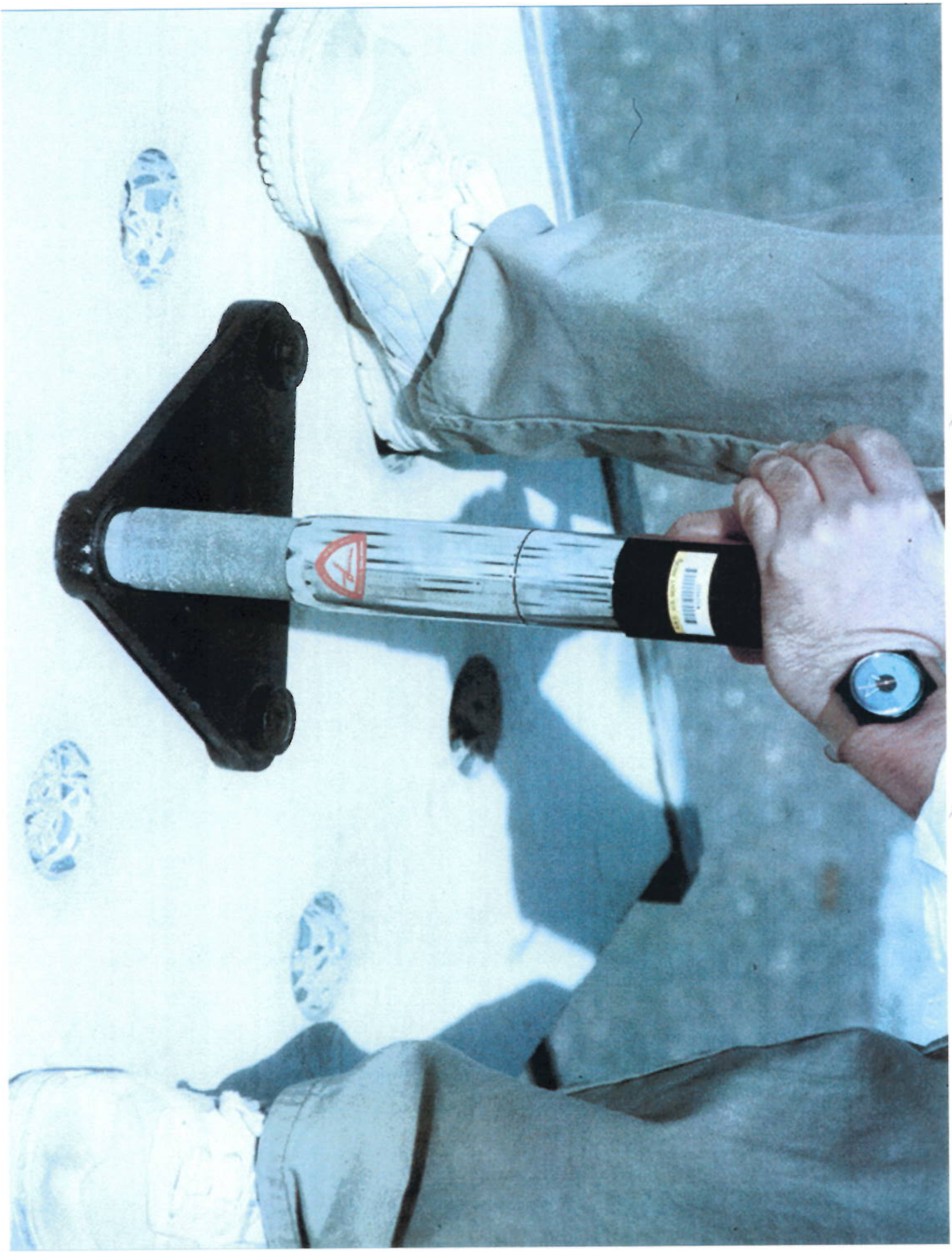


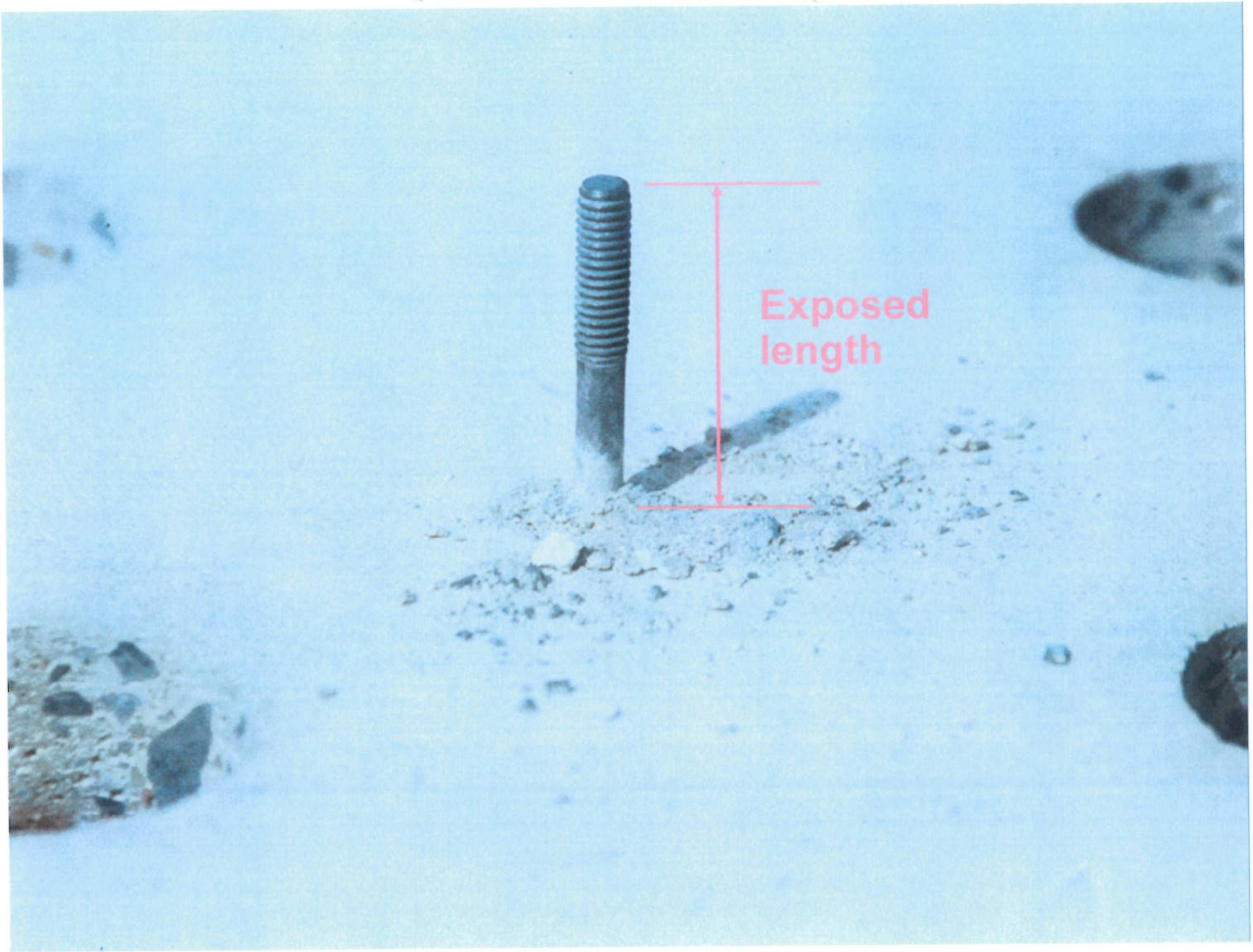
Ward, M.A. and Langan, B.W., *Cement Concrete and Aggregates*, 16(2), Dec. 1994, 181-185

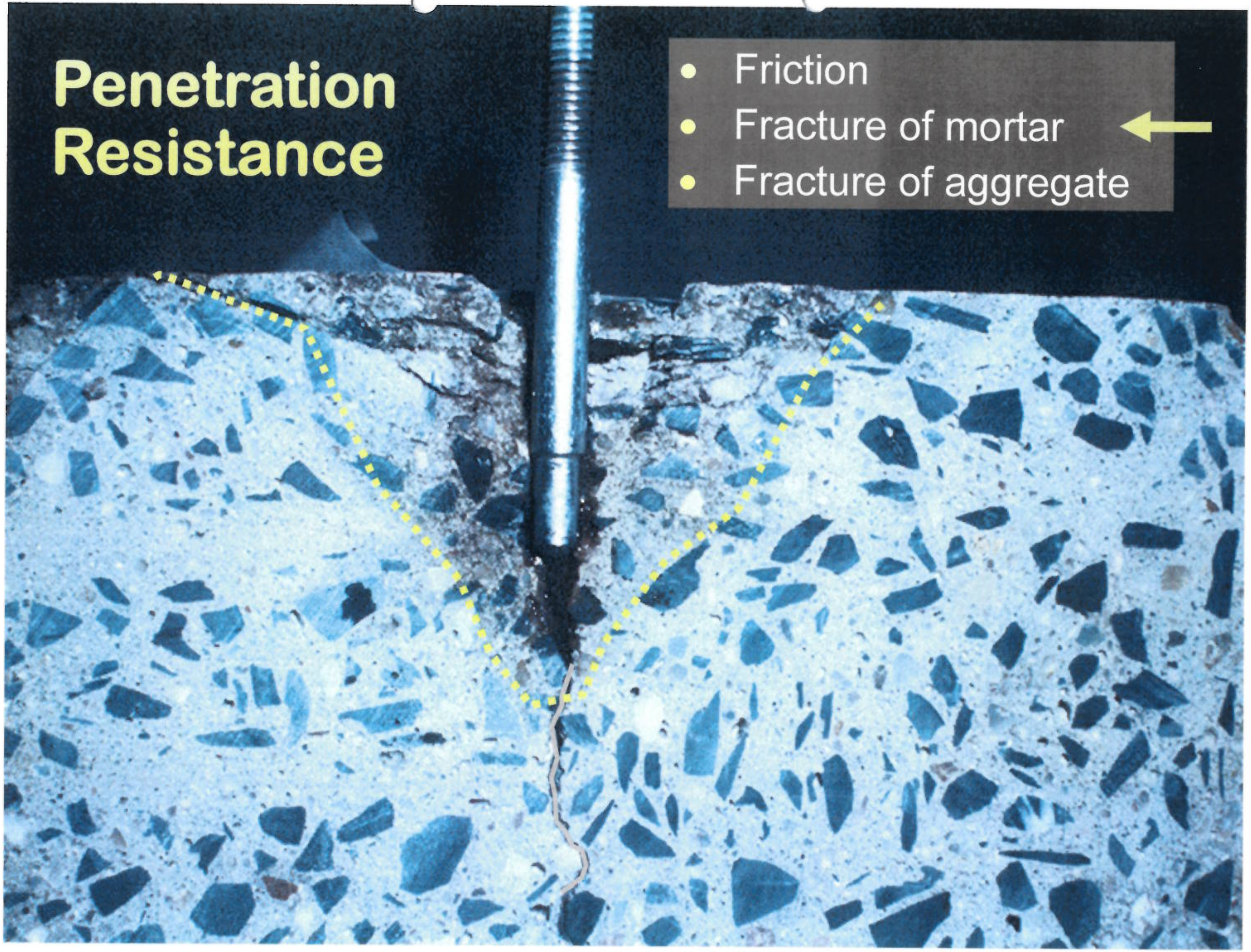
ASTM C803/C803M Penetration Resistance of Hardened Concrete

- Measure depth of penetration of probe or pin driven into concrete.


"Gold" probe for LW and low-strength concrete
Cartridge
PARAGON 56 3280
"Silver" probe for normal density concrete




Exposed
length


Penetration Resistance
Friction
Fracture of mortar
Fracture of aggregate

"Calibration" Table

STANDARD POWER-TABLE NO. 1

EXPOSED PROBE (Inches)	COMPRESSIVE STRENGTH (p.s.i.) Mohs' No. 3	Mohs' No. 4	Mohs' No. 5	Mohs' No. 6	Mohs' No. 7
1.275	-	-	-	-	-
1.300	-	-	-	-	-
1.325	-	-	-	-	-
1.350	-	-	-	-	-
1.375	-	-	-	-	-
1.400	3000	-	-	-	-
1.425	3175	-	-	-	-
1.450	3325	-	-	-	-
1.475	3500	-	-	-	-
1.500	3675	3000	-	-	-
1.525	3825	3175	-	-	-
1.550	4000	3350	-	-	-
1.575	4175	3525	-	-	-
1.600	4325	3700	3050	-	-
1.625	4500	3875	3225	-	-
1.650	4675	4050	3400	-	-
1.675	4825	4225	3600	-	-
1.700	5000	4400	3775	3000	-
1.725	5175	4575	3950	3200	-
1.750	5325	4750	4150	3400	-
1.775	5500	4925	4325	3600	-
1.800	5675	5100	4500	3800	3000
1.825	5825	5275	4700	4000	3225
1.850	6000	5450	4875	4200	3425
1.875	6175	5625	5050	4400	3650
1.900	6325	5800	5250	4600	3875

WINDSOR PROBE TEST SYSTEM

IMPORTANT INSTRUCTIONS

This Table is used only for the STANDARD POWER range of the Windsor Probe System, operated in accordance with the manufacturers Instruction Manual.

The Table represents the results of calibrating the system to the velocity of the probe at the STANDARD POWER position.

STANDARD POWER is used for testing concrete, in existing structures, usually cured longer than 28 days.

ALWAYS change to LOW POWER if the Probe System, used at standard power, indicates less than 3000 psi.

This Table, No. 1, has no fixed relationship to Table No. 2. Each Table has been calibrated independently to the respective probe velocity. A point of convergence will occur in the range of 3600 psi, and vary slightly, depending on the design mix.

NOTE: If the speed (velocity) of a crushing press was changed for breaking standard

Mohs Hardness Scale

MINERALS

In the Scale of Hardness

The determination of the hardness of a mineral can be an important step toward its identification. The term hardness is used with a special meaning for the mineralogist. It is the resistance which the smooth surface of a mineral offers to being scratched. A diamond is the hardest of all substances and can be scratched only by another diamond.

Over a century ago, Friedrich Mohs by experimentation made up a scale of hardness which is sometimes referred to as Mohs' scale. It does not imply an exact hardness, but is set up so that any mineral can scratch all those beneath it in the scale, or can be scratched by those above it in the scale.

Since diamond is the hardest it is given number 10; talc is the softest so is given number 1. Quartz number 7 is often used as a division in the scale and all those above 7 are called the hard minerals.

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond (not included)

Some very familiar objects can be used in conjunction with this scale. A fingernail has the hardness of 2½, a copper coin between 3 and 4, a knife blade or common window glass 5½, a steel file 6½. Other minerals are sometimes substituted in the scale such as topaz for beryl since they both have a hardness of 8. Carborundum is a manufactured product and sometimes more easily available than corundum or diamond.

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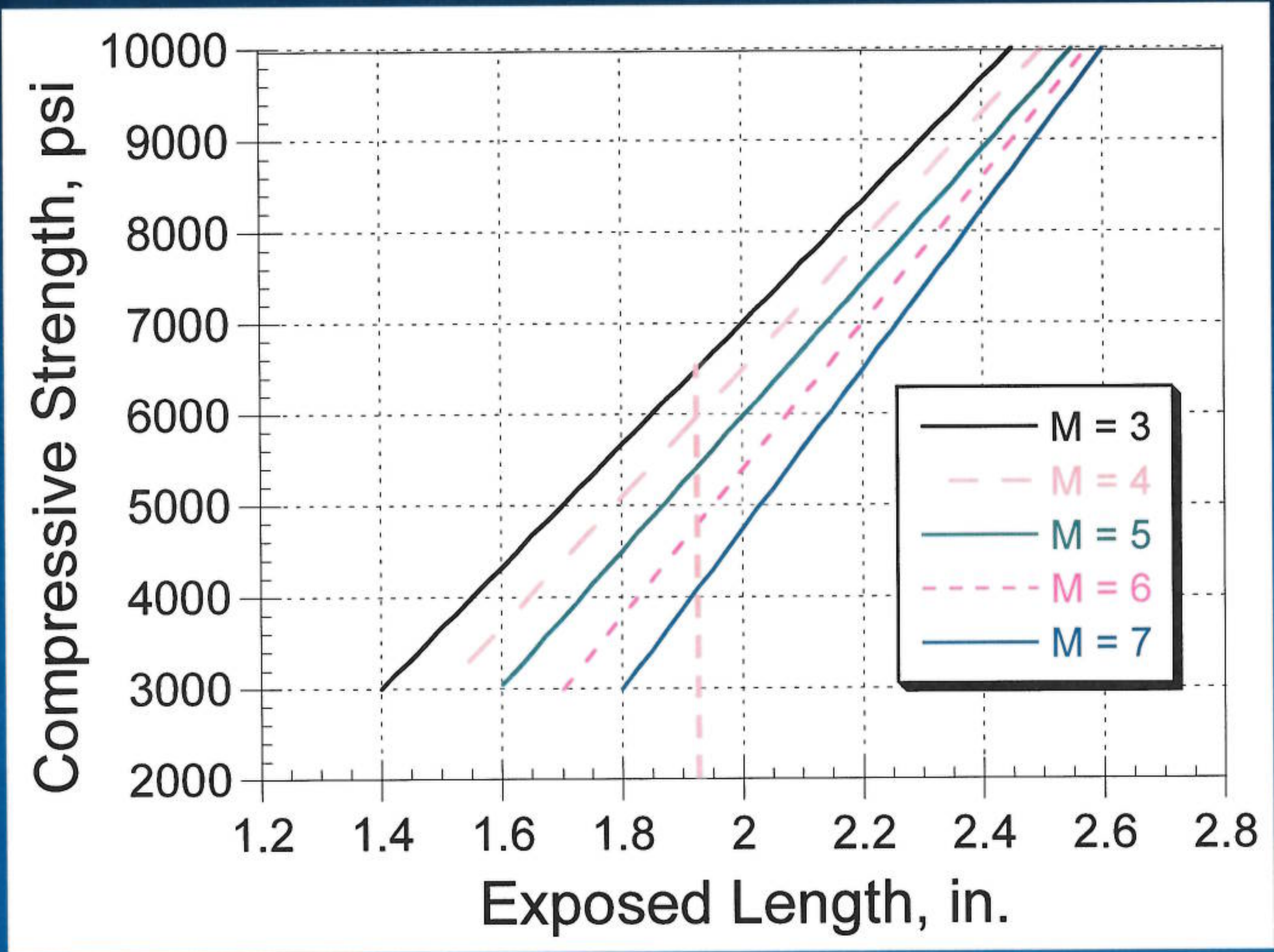
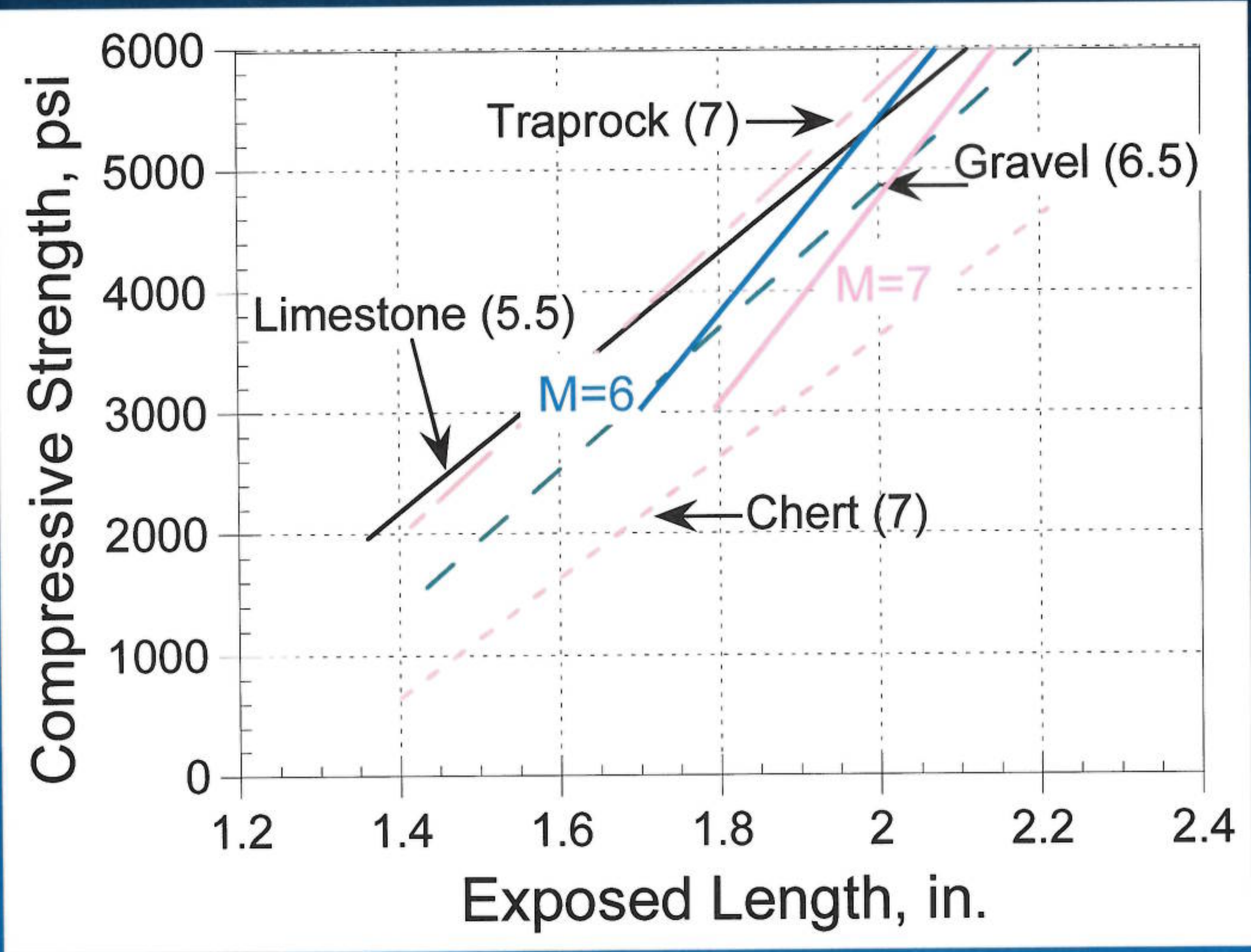
Ft. Collins, CO 80522

“Calibration” Table

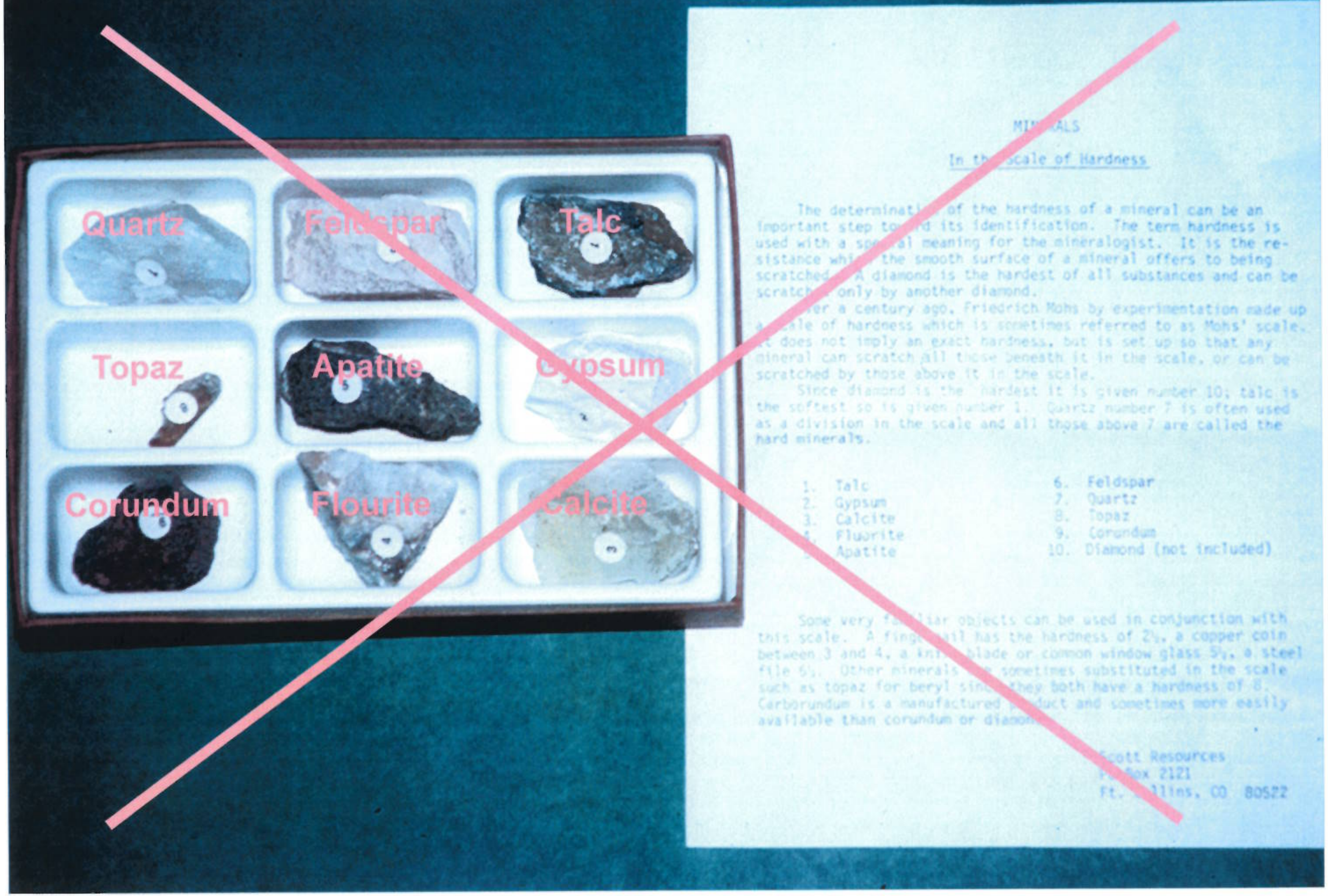


Test Data



Ref: Malhotra, V.M., *Materials and Structures*, 7(37), 1974

Mohs Hardness Scale



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