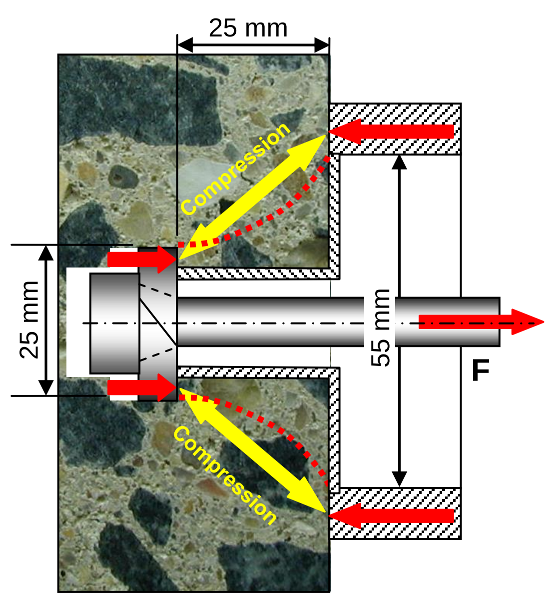
Purpose

The **CAPO-TEST** system is used to obtain a reliable estimate of the on-site compressive strength of concrete on existing structures in accordance with the pullout test method described in ASTM C900, BS 1881:207, or EN 12504-3. Unlike **LOK-TEST**, requiring cast-in inserts, the **CAPO-TEST** can be performed without the need of such pre-installed inserts. The main applications of **CAPO-TEST** are:

- QA / QC testing of the finished structure.
- Evaluation of curing conditions, testing of the **"peel"** protecting the reinforcement.
- Verification of in-place strength if strength of standard-cured specimens fails to meet acceptance criteria.
- Estimating strength of concrete in evaluation of existing structures.
- Timing of safe and early loading.
- Evaluation of fire-damaged structures.

Principle

The surface at the test location is ground (or planned to a required depth) using a grinding planning tool, and an 18.4 mm hole is cored perpendicular to the surface using a diamond coring bit. A recess (slot) is routed in the hole to a diameter of 25 mm and at a depth of 25 mm from the planned surface. A split ring is expanded in the recess and pulled out using a pull machine reacting against a 55 mm diameter counter pressure ring. As in the **LOK-TEST**, the concrete in the strut between the expanded ring and the counter pressure ring is in compression. Hence, the ultimate pullout force **F** required to pullout the ring is directly a measure of the compressive strength.



The test is performed until the conic frustum between the expanded ring and the inner diameter of the counter pressure is dislodged. There will be a minor surface damage (the small cone hole), which can be easily patched with a repair mortar for aesthetic purposes or to avoid potential durability problems.

Correlation and Accuracy

CAPO-TEST provides in 10-15 minutes an accurate estimate of in-place strength based on a well-defined general correlation to compressive strength measured using either standard cylinders or cubes.

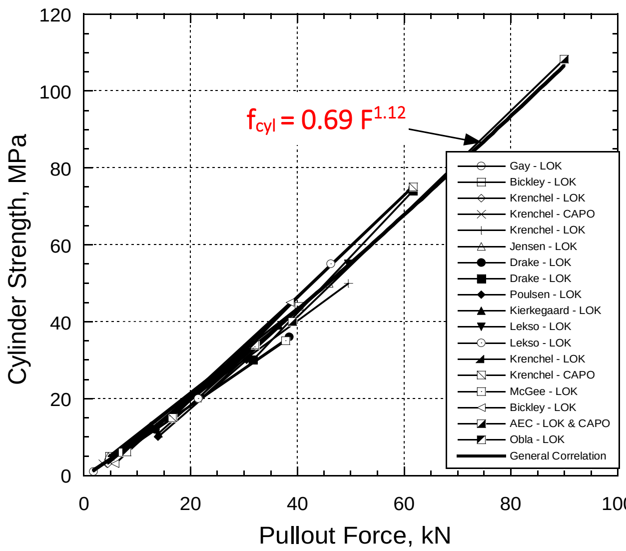
The results are not influenced by surface conditions, such as texture, moisture content, hardness or depth of carbonation, as are other methods like the rebound hammer, the ultrasound pulse velocity (UPV) or the Windsor probe. Thus, the CAPO-Test can be used with confidence without having to take and test a large number of cores to develop a site-specific correlation.

More than 40 years of correlation experience with **LOK-TEST and CAPO-TEST** from all over the world indicates that **one general correlation** can be applicable for all normal density concrete mixtures, with small scatter and very sensitive relationship, [2) 6) 7) 8) 11) and 12)]

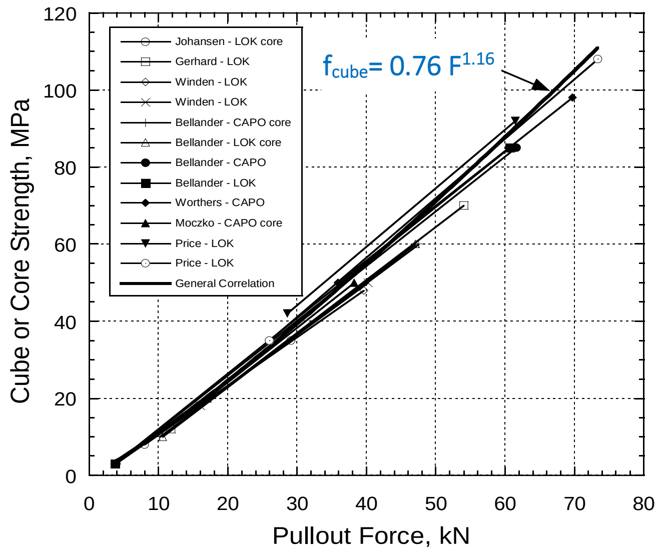
The general correlations between pull-out force and standard compressive strength shown in the following figures are from 30 major independent correlation studies and provide sufficient accuracy for normal density concrete mixtures. The studies were performed by various laboratories in Denmark, Sweden, Norway, Holland, Canada, the United States, Poland, and England. It has been shown that these general correlations are not affected by types of cementitious materials, water-cementitious materials ratio (w/cm), maturity, use of self-consolidating concrete, air entrainment, admixtures, curing conditions, stresses in the structure, stiffness of the member, carbonation, as well as shape, type, and size of aggregate up to 38 mm.

Several investigations have shown that the pullout strength measured by the **CAPO-TEST** is essentially the same as the pullout strength measured by **LOK-TEST**. This equality is illustrated next page in the graph on the right, which includes data from six independent studies. Thus, the general correlations are valid for both test systems.

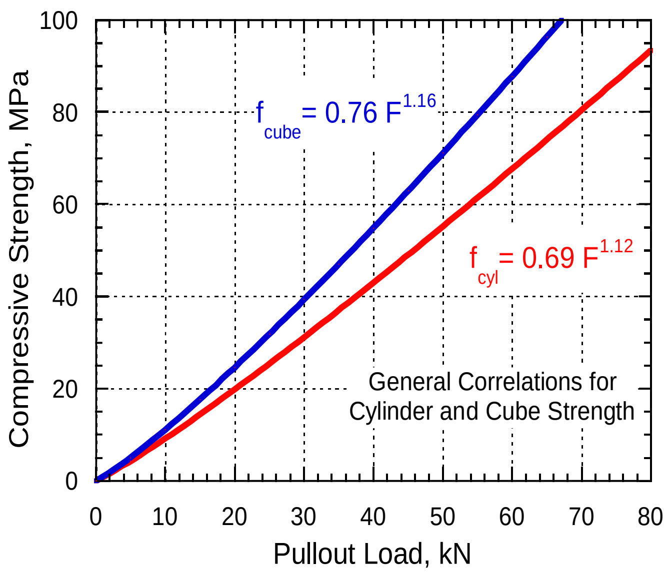
Variation of the **CAPO-TEST** on lab specimens range from 4.5% to 7.5% depending on type of specimen, and on-site from 7.8% to 12.5% for uniform batches delivered. Twenty-five dubious structures, reported in 1984 [6)] exhibited variations from 9.0% to 25.5%, averaging 14.7%. A later report from 1994 [7)] showed similar variations on-site.



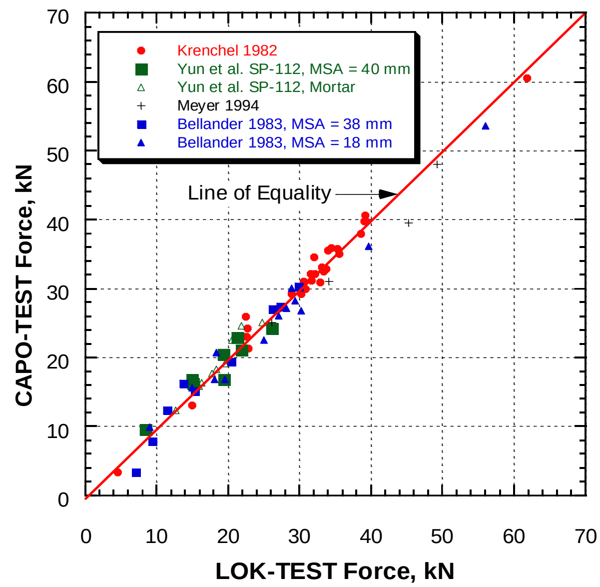
18 correlations between pullout force and standard cylinder strength [4)]



12 correlations between pullout force and standard cube strength or cores (100 mm x 100 mm) [4)]



The robust general correlations to standard cylinders and cubes (or cores) using either LOK-TEST or CAPO-TEST



Comparison of results between the pull-out force given by LOK-TEST and CAPO-TEST

Performed in accordance with ASTM C900 or EN 12504-3 these robust correlations are documented and discussed in refs [2, 3, 6, 7, 8, 9, 22 and 12]. Project specifications, however, may require development of mixture specific correlations. What is important in such correlations is that they are performed on exactly same concrete quality. ACI 228.1R gives guidance on how to develop such relationships [18].

CAPO-TEST Application Examples

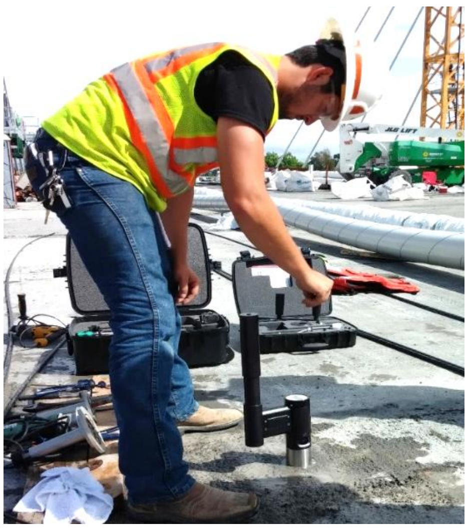
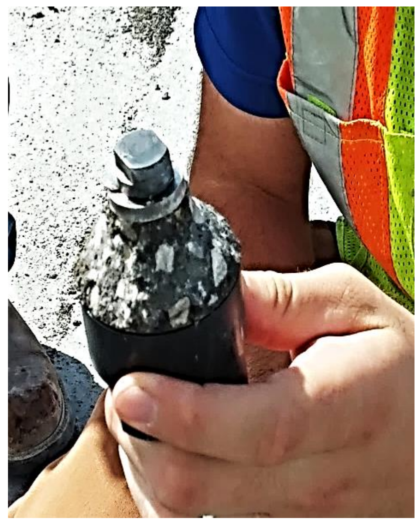
Column being tested for strength acceptance, Mexico

Testing the curing conditions of the "peel" protecting the reinforcement, Great Belt Link project, Denmark

Dubious beam being tested for strength, Denmark



Strength evaluation of 15 bridges (25 to 52 years old) on carbonated concrete, Poland

Testing of bridge joint before final loading, USA. Adjacent, the CAPO pullout cone

Strength testing of shotcrete, mine shaft, Canada

Structural evaluation of a railway bridge, Mexico

Quality assurance of tunnel lining segments, Channel Tunnel, UK

CAPO-TEST Specifications

- Battery powered handheld hydraulic pulling machine with an electronic precision gauge and robust steel-aluminum body
- Digital display resolution = 0.1 kN
- Maximum force: 100 kN
- Maximum stroke: 6 mm
- Accuracy of measurements: ± 2%
- Operating conditions: -10 to 50°C, max. RH = 95%
- Memory capacity: 512 measurements (peak-value, time and date of testing)
- USB interface
- AMIGAS Software for PC communication and printout
- 710 W, 24 000 rpm, variable speed, compact electric router
- 650 W, 2 800 rpm, 9 Nm torque, variable speed electric drill
- High performance diamond drill bit, router bit and planning wheel

CAPO-TEST Ordering Numbers

Two versions are available, the C-1000 Capo-Test complete system and the C-2000 Capo-Test Lite.

C-1000 CAPO-TEST Complete System. Includes the C-101 Preparation Kit, the C-102 DSV-Kit, and the C-104 pull machine kit:

C-101 CAPO Preparation Kit

For location of reinforcement, planning surface, drilling the center hole and routing the recess to accommodate the expandable insert. It also contains the unit for expanding the insert, counter pressure and other tools for conducting the test.

Item	Order #
Counter pressure	C-142
Expansion unit	C-101-1
Coupling	C-141
Water pump	C-150
Recess router unit	C-101-2
Distance piece, 25 mm	C-136
Bottle w. CAPO-Oil	C-143
Diamond drill unit	C-101-3
Red diamond drill bit	C-101-3-1
Wrench, 13 mm	C-170
Wrench, 14 mm, 2 pcs	C-151
Wrench, 17 mm, 2 pcs	C-171
Wrench, 19 mm, 2 pcs	C-155
Surface planer unit	C-102-1
Diamond planning wheel	C-102-11
Centering brass rod	C-102-5
Reinforcement locator	C-180
Screwdriver	C-149
Tweezers	C-148
Plastic hose, 2 pcs	C-157
Marking chalk	C-160
Allen key, 4 mm	C-156
Wrench, 46 mm	C-147-1
Adjustable wrench	C-147-2
Vernier caliper	C-135
Attaché case with tray	C-160
Electric drill machine	C-101-4

C-102 SV-Kit

Includes a support suction plate and a vacuum pump as auxiliary tools for testing. The suction plate controls the planning, the coring of the center hole and the routing of the recess.

The green diamond coring bit is longer than the red one supplied in the preparation kit (C-101-3-1) to accommodate the extra height of the suction plate.

There must be sufficient space (350 mm in diameter) and a rather smooth and airtight concrete surface for activation of the suction plate.

Item	Order #
Vacuum pump	C-102-4
Suction plate	C-102-2
Green diamond drill bit	C-101-3-2
Clamping pliers, 2 pcs	C-102-3
Small screwdriver	C-158
Plastic hose with nipple	C-147
Attaché case	C-161

C-104 CAPO Pull Machine Kit

Includes the hydraulic pull machine, max. 100 kN capacity, and accessories.

The same pull machine can be used for the **LOK-TEST** and the **BOND TEST** with a few additional accessories (see the corresponding technical datasheets).

Item	Order #
Hydraulic pull machine with electronic gauge	L-11-1
AMIGAS printing software	L-13
USB Cable	L-14
Oil refilling cup	L-24
Oil refilling bottle	L-25
Large screwdriver	C-149
Small screwdriver	C-157
Calibration table	L-32
Manual	L-33
Attaché Case	C-104-1

C-2000 CAPO-TEST Lite. This compact kit includes all the essential parts and accessories to perform the CAPO-TEST without the auxiliary vacuum tools.

Item	Order #
CAPO-TEST Lite Contains all the parts of the C-101 CAPO Preparation Kit and the C-104 CAPO Pull Machine Kit.	C-2000

Additional items for both versions

C-112 Expandable inserts *(one per test)*

C-111 Resizing Tool
For reusing C-112 inserts 2 to 3 times

L-30 Load Verification Unit

The calibration of a pull machine is recommended to be verified at least once a year, after servicing or after repair.

The **L-30** Load Verification Unit has a working range of 0 to 100 kN and ensures that the load displayed by the pull machine is within ±1 % of the actual load, as required by ASTM C900. The load is displayed to the nearest 0.1 kN.

References

CAPO-TEST Instruction video on our YouTube channel: ”CAPO-TEST ASTM C-900”

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3. Carino, N.J.: “In-Place Strength without Testing Cores, the Pullout Test”, 6th International Seminar on Advances in Cement and Concrete Technology for Sustainable Development, China, March 2018.
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16. European Standard EN 13791: “Assessment of In-Situ Compressive Strength in Structures and Precast Concrete Components”, European Committee for Standardization (CEN), Brussels, Belgium, 2005, 29 pp.
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18. ACI Committee 228, “In-Place Methods to Estimate Concrete Strength”, American Concrete Institute.
19. **PPT in three sections on Germann Instruments homepage www.germann.org describing the fundamentals of CAPO-TEST and LOK-TEST**
    Section 1: Theoretical analysis, fracture mechanism and correlations
    Section 2: Rationale, testing cases and standards
    Section 3: Hardware, testing procedure and instruments