CAPO-TEST

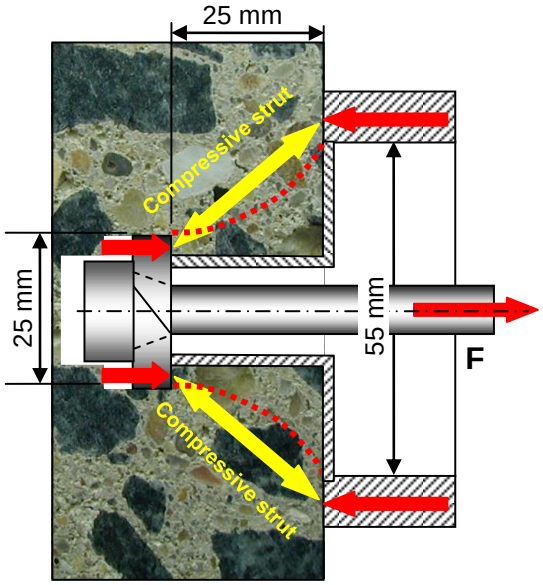
Purpose

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**, the **CAPO-TEST** can be performed without the need of pre-installed inserts and therefore, can be used for:

- Quality assurance testing of the finished structure.
- 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.
- Evaluation of fire-damaged structures.

Principle

The surface at the test location is ground using a planing tool and a 18.4 mm hole is made 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. 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 related directly to compressive strength.



The test is performed until the conic frustum between the expanded ring and the inner diameter of the counter pressure is dislodged. Thus, there is minor surface damage, which can be easily repaired for aesthetic reasons or to avoid potential durability problems.

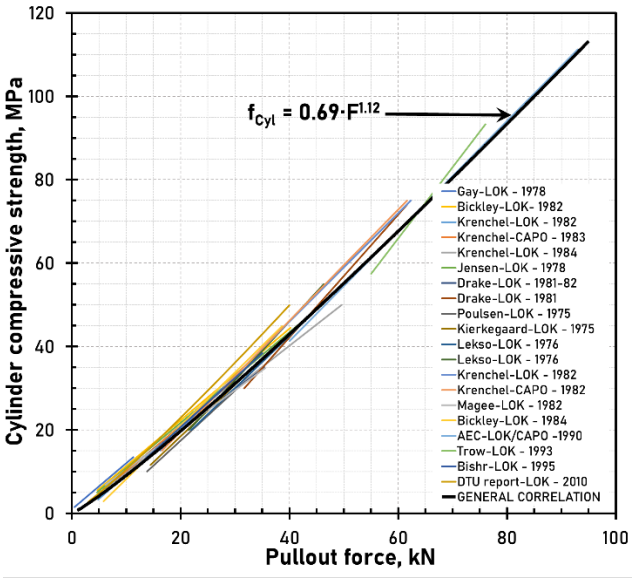
Correlation and Accuracy of Estimated Strength

CAPO-TEST provides an immediate and accurate estimate of in-place strength because the peak pullout force has a well-defined correlation to compressive strength measured using standard cylinders or cubes. Test methods to estimate compressive strength like rebound hammer (Schmidt hammer), ultrasonic pulse velocity or Windsor probe, require to develop particular correlations for every concrete mixture. By contrast, the more than 30 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. A significantly different correlation, however, has been found for concrete made with lightweight (low density) aggregate.

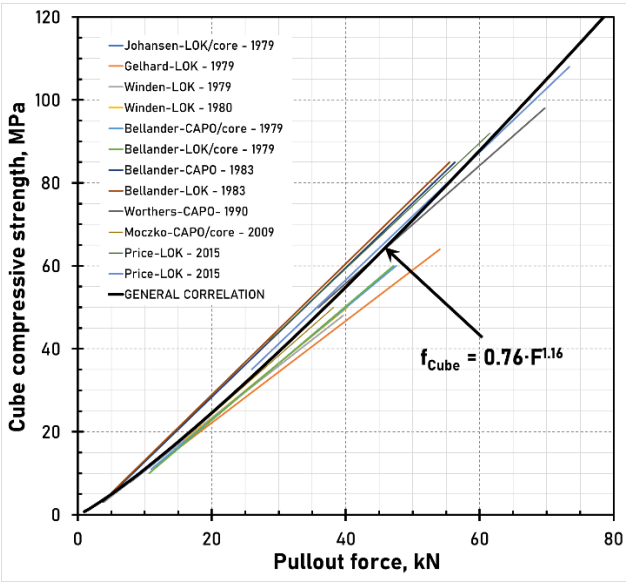
The general correlations between pull-out force and standard compressive strength shown in the following figures are product of about 30 major independent studies and provide sufficient accuracy for normal density concrete mixtures. The studies were performed by various laboratories in Denmark, Sweden, Norway, Holland, Canada, the United States, Poland, and England.[1,2] 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, normal amounts of air entrainment, use of admixtures, curing conditions, stresses in the structure, rigidity 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 in the graph on the bottom right, which includes data from four independent studies. Thus, the general correlations are valid for both test systems.

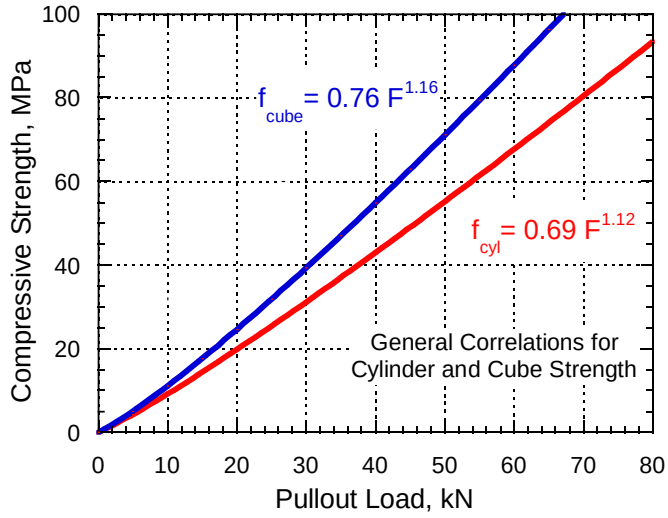
At the 95 % confidence level and for an average of 4 tests, the estimated compressive strength based on the **CAPO-TEST** and the general correlations indicated is within ± 6 % of the strength measured from tests of standard specimen (cylinders or cubes) for a maximum aggregate size of 38 mm. The coefficient of variation of individual **CAPO-TEST** results is about 8 % for normal density concrete.



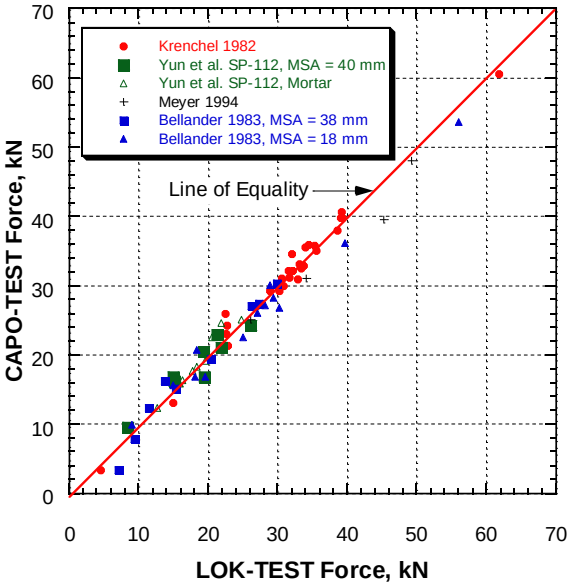
The best-fit curve to 18 correlations between pullout force and the compressive strength of 150 x 300 mm (6 x 12 in.).



The best-fit curve to 12 correlations between pullout force and compressive strength of 150 mm (6 in.) cubes



The robust general correlations to standard cylinders and cubes

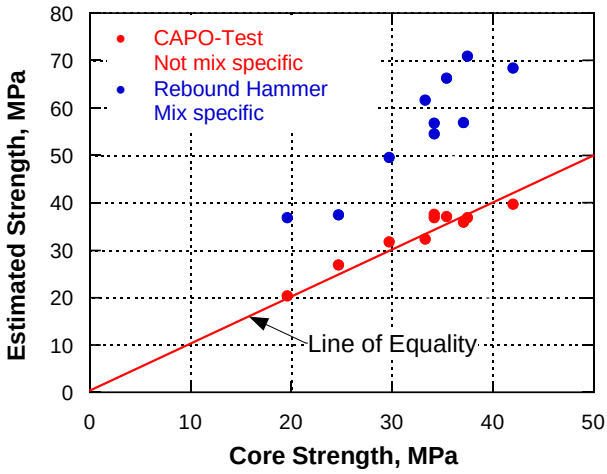


Comparison of results between the pull-out force given by LOK-TEST and CAPO-TEST

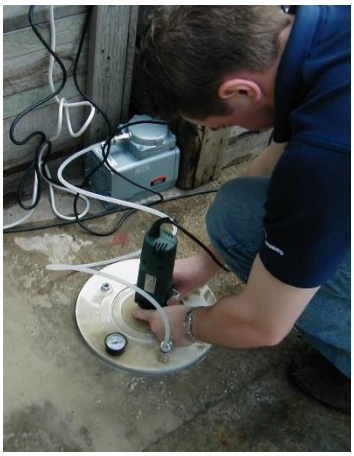
The reason why the failure mechanism of LOK and CAPO tests performed in accordance with ASTM C900 or EN 12504-3 gives these very robust correlations is discussed in references 4 and 5. Project specifications, however, may require development of mixture specific correlations. In this case, ACI 228.1R gives guidance on how to develop such relationships[6].

Comparison with Core Strength

An investigation on 10 bridges[3] compared the strength of cores with strengths estimated on the basis of the **CAPO-TEST** and the rebound hammer test (ASTM C805, EN 12504-2). As shown in the figure, strengths estimated by the **CAPO-TEST** were on average within 6 % of the core strength. This study confirms the inherent reliability of pullout testing for estimating in-place compressive strength. The effect of carbonation had no influence on the **CAPO-TEST** results[5].



Example Applications



Routing recess for preparation for **CAPO-TEST** *to evaluate surface strength of an industrial floor slab*

View of valid **CAPO-TEST** *of a slab. Note the well-formed failure ring on the surface of the slab.*

CAPO-TEST *being performed in parking garage to evaluate in-place strength of suspect concrete*

CAPO-TEST Specifications

- Battery powered handheld hydraulic pulling machine with 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 planing wheel
- Optional auxiliary vacuum pump and support plate

CAPO-TEST Ordering Numbers.

Two versions of the system are available.

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

To drill the center hole and to cut the recess to accommodate the expandable insert. It also contains the unit for expanding the **CAPO-TEST** insert 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-101-31
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 planing 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

It includes a support suction plate and a vacuum pump as auxiliary tools for testing. There must be sufficient space (350 mm in diameter) and a rather smooth and airtight concrete surface.

Item	Order #
Vacuum pump	C-102-4
Suction plate	C-102-2
Green diamond drill bit	C-101-32
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

It includes the 100 kN hydraulic pull machine and accessories.
The same pull machine can be used for the **BOND TEST** and the **LOK-TEST** (see their technical data sheets).

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

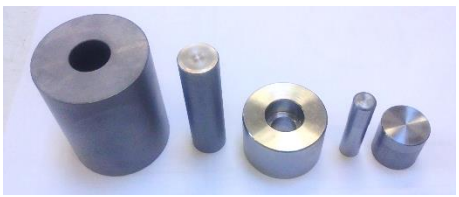
C-2000 CAPO-TEST Lite. This compact kit includes the hydraulic pull machine and all the essential accessories to perform a test without the auxiliary vacuum tools.

Item	Order #
CAPO Pull Machine Kit (all items except attaché case)	**C-104**
CAPO Preparation Kit (all items except Surface planner unit* and attaché case)	**C-101**
Large attaché case for CAPO Lite	C-200

**Diamond planning wheel and drill bit are both used with the diamond drill unit.*

Inserts and Resizing Tool

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



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

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 2 % of the actual load, as required by ASTM C900. The load is displayed to the nearest 0.1 kN.

References

1. Petersen, C. G., "LOK-TEST and CAPO-TEST Pullout Testing, Twenty Years' Experience," NDT in Civil Engineering Conference, Liverpool, UK, Apr. 1997, 19 pp.
2. Krenchel, H., and Petersen, C. G., "In-Situ Pullout Testing with LOK-TEST, Ten Years' Experience," Presentation at Research Session of the CANMET/ACI International Conference on In Situ/Nondestructive Testing of Concrete, Ottawa, ON, Canada, Oct. 1984, 24 pp.
3. Moczko, A., "Comparison Between Compressive Strength Tests From Cores, CAPO-TEST and Schmidt Hammer," Wroclaw Technical University, Poland, 2002.
4. Moczko, Carino, and Petersen, "CAPO-TEST to Estimate Concrete Strength in Bridges", ACI Materials Journal, Technical Paper No. 113-M76, V. 113, No. 6, November-December 2016, pp. 827 – 836.
5. Carino, N. J., "Pullout Test," Handbook on Nondestructive Testing of Concrete, second edition, V. M. Malhotra and N.J. Carino, eds., CRC Press, Chapter 3, 2004, 36 pp.
6. ACI Committee 228, "In-Place Methods to Estimate Concrete Strength", American Concrete Institute.