CAPO-TEST

CLAUS GERMANN PETERSEN

UDK 666.97.017:620.179

BACKGROUND

With lok-test, ref. (1) a cast-in disc is pulled towards a counterpressure tube placed on the concrete surface. The pull-force (lok-strength) is applied up to a required strength or to failure of the concrete. Experimentally, (1)–(9), as well as theoretically, (10), (11), it has been found that the pull-force is proportional to the compressive strength.

The use of lok-test is however limited to planned testing of new structures since the disc has to be fixed in the forms before or during concreting.

For testing existing structures at random there has been a need for a similar technique drilled or cut in the concrete. Attempts to do so have been reported in (12) and (13). However these methods measure properties other than the compressive strength. Also the reproducibility is not convincing.

According to a finite element analysis of the failure mechanism, (11), the lok-test geometrical proportions under loading provide a narrow symmetrical band of compression stresses running from the disc surface towards the counterpressure tube as illustrated in figure 1.3. This causes a crushing of the concrete making the lok-strength directly dependent on the concrete compressive strength. To preserve this essential property in a new pull-out test applied to hardened concrete it is therefore of importance to keep the basic lok-test proportions.

METHOD

For this purpose a special undercutting and subsequent expanding ring technique was developed through experiments and tests made in the past seven years ensuring a standardized installation of the insert first of all guaranteeing a correct circumferential connection between the expanded insert and the undercut groove surface parallel to the concrete surface. In this way the mechanism of failure would be the same as that of lok-test.

Named after the fundamental operations in the testing procedure the test was called Cut And Pull-Out test or CAPO-TEST.

Compared with the steps in a lok-test as illustrated in figure 1, the capo-test procedure is shown in figure 2.

The first step in a capo-test is to drill an 18 mm hole 45 mm deep in the concrete perpendicular to the surface. Second, the undercutting of the 25 mm groove in a depth of 25 mm takes place (figure 2.1). Third, the ring insert is placed in the hole and expanded to a 25 mm diameter dimension in the groove as illustrated in figure 2.2. Fourth a normal lok-test pullmachine is fixed to the insert which is pulled out through a counterpressure tube with an inner diameter of 55 mm and a outer diameter of 70 mm as shown in figure 2.3. Figure 2.4 illustrates the minor disruption of the concrete surface after testing.

In a pilot test program in 1975 the lok-strength was compared with the capo-strength in the surface of a 20 cm slab. On the basis of 20 tests of each type made on this normal type of concrete with 16 mm maximum size sea gravel aggregates the pull-forces were averaged 25,9 kN lok-strength and 24.1 kN capo-strength with coefficients of variation of 4.6% and 5.3%, respectively. It was also interesting to observe the identical forms of the concrete cones if pulled out as well as the splitting of the aggregates in the failure zone that took place (shown in figure 3). These phenomena indicated a similar stress pattern and failure mechanism in both tests, and hence a sufficient undercutting and expansion technique of the capo-test.

The capo-test equipment used for this and the following research tests was developed to ensure a standardized testing procedure. It is shown in figure 4 in its final stage.

RESEARCH

On the basis of the preliminary experience with capo-test the Structural Research Laboratory of the Technical University of Denmark conducted in 1979 a research project to evaluate the reliability and reproducibility of the new method relative to lok-test and to cylinder compressive strength.

The project and its results have been published (14) and are summarized as follows. Four types of concrete were investigated, 1. Normal concrete with ordinary aggregates 2. Lightweight concrete, 3. Gunite concrete and 4. Vacuum concrete. The main investigation covers the first type of concrete, and this article will only deal with this part.

28 mixes were made. Variables considered were water-cement ratio, source of aggregates (sea gravel and crushed granite), size of aggregates (8,16 and 32 mm maximum particle size), curing conditions, age and air entrainment. The concrete qualities ranged from 14 MPa (2030 psi) to 74 MPa (10730 psi) measured on standard cylinders (150 mm × 300 mm).

From each mix a number of cylinders and a similar number of cubes (200 × 200 mm) were cast. The numbers varied between 2 and 12 depending on the property investigated. In each cube lok-test inserts were cast placed central in two of the opposite vertical surfaces. The cylinders and the cubes were cured under the same conditions, and on the day of testing the cylinders were crushed and the cubes tested with lok-test and with capo-tests made in the two remaining vertical surfaces.

The total numbers of tests comprised 116 cylinders, 216 lok-tests and 214 capo-tests on this normal type of concrete.

A plot of the average values from each mix is given in figure 5 showing lok-strength relative to cylinder strength and in figure 6 capo-strength relative to cylinder strength. It should be noted that the average points shown are based on different numbers of tests. But for a mutual comparison between lok-test and capo-test the illustrations should give a good overview.

For the statistical analyses the observations were weighted depending on the numbers of tests in each mix. The analyses showed straight line relationships with coefficients of correlation on single observations of both lok-test and capo-test of 0.96 in relation to cylinder compressive strength.

With lok-strength "L" and capo-strength "C" measured in kN pull-force and cylinder compressive strength "f_c" measured in MPa the relations were calculated to be:

$$L = 0.77 \cdot f_c + 4.4$$

$$C = 0.77 \cdot f_c + 4.5$$

The coefficients of variation within each mix for cylinders were found to average 3.7%, ranging from 1.2% to 6.6%, for lok-test to average 7.1%, ranging from 1.6% to 14.9%, and for capo-test to average 7.1%, ranging

Figure 1. LOK-TEST procedure

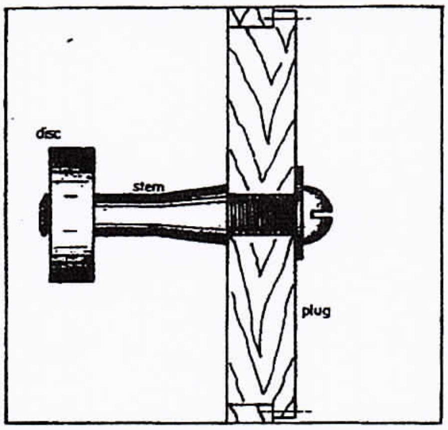


Figure 1.1
Placing of insert in form (shown here for early form-stripping purpose).

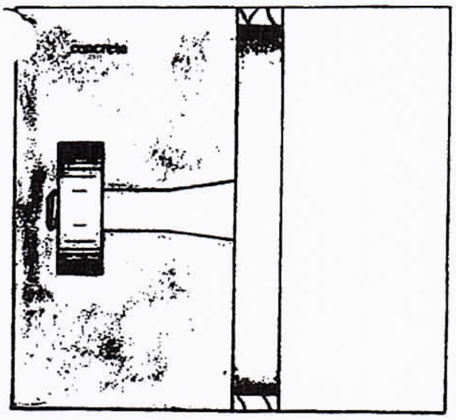


Figure 1.2
Removal of plug in form and stem

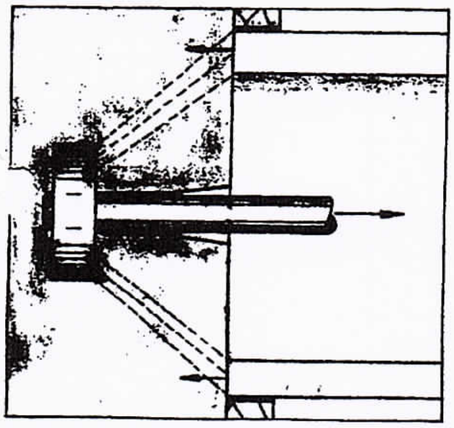


Figure 1.3
Placing of pull-machine and loading (compression stress lines dotted).

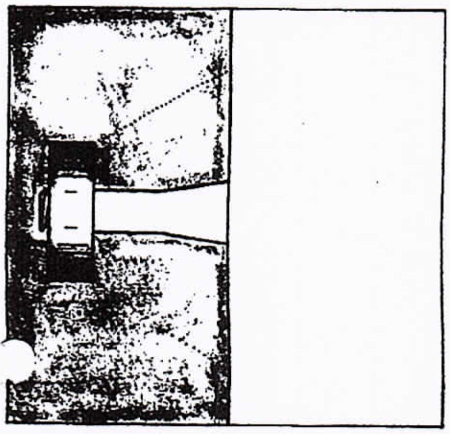


Figure 1.4
Removal of pull-machine and form.

Figure 2. CAPO-TEST procedure.

Figure 2.1
Drilling and undercutting.

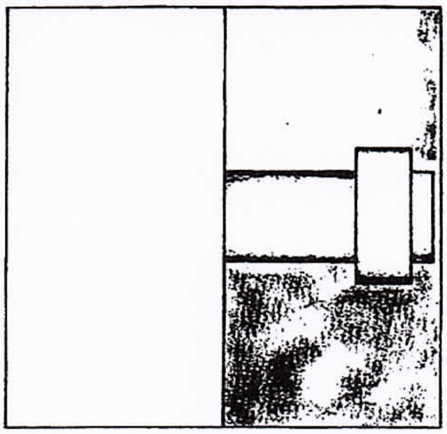


Figure 2.2
Placing and expansion of the ring insert.

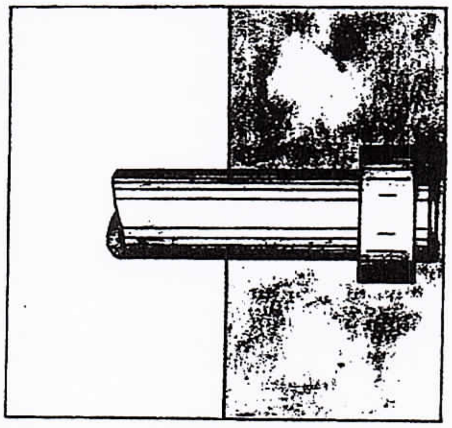


Figure 2.3
Placing of pullmachine and loading to failure.

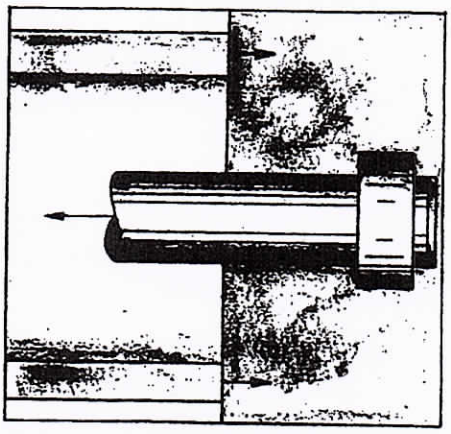
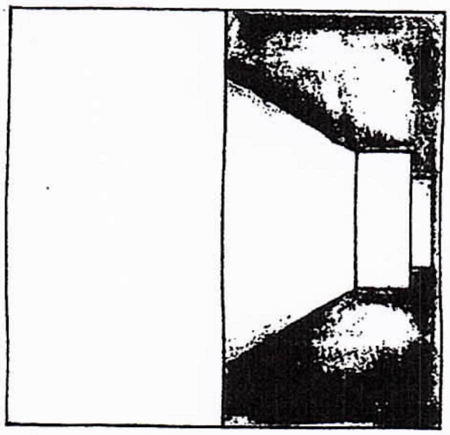


Figure 2.4
Rupture pattern after test.



from 2.6% to 12,9%. It is concluded in (14) that capo-test has the same reliability and reproducibility as lok-test based on the present case covering normal type of concrete in the quality range from 14 MPa (2030 psi) to 74 MPa (10730 psi) with ordinary types of aggregates and with maximum particle size up to 32 mm.

The correlation between capo-strength and cylinder strength does not differ significantly from earlier findings of the correlation between lok-test and cylinder strength as referred to in (1) to (9).

EXPERIENCE WITH CAPO-TEST

In a special test in the above referred research program, the capo-test was used to evaluate differences in strength at the top and bottom of the 200 x 200 mm cubes. In one mix 12 capo-tests were made in the top and 12 in the bottom and compared with 12 tested in the middle of the cubes. Average strength in the top was 19.0 kN, in the middle 24.3 kN and in the bottom 27.0 kN, showing significant increasedly strength towards the bottom face. This phenomenon has also been observed by others (3), (8), and is undoubtedly caused by better consolidation of the concrete towards the bottom.

Capo-test has been in use in Denmark on a number of sites. It takes approximately 8 minutes for one test provided the necessary electricity and water supply is present. The diamonds for drilling and undercutting have a life of between 50 and 100 tests. The capo-inserts are resuable two or three times. The testing personnal must be trained in testing with capo-test and should have experience with concrete testing practices.

Figure 3. Lok-test and capo-test failure cones pulled out of 25 MPa (3600 psi) concrete with sea gravel aggregates, maximum particle size 16 mm.

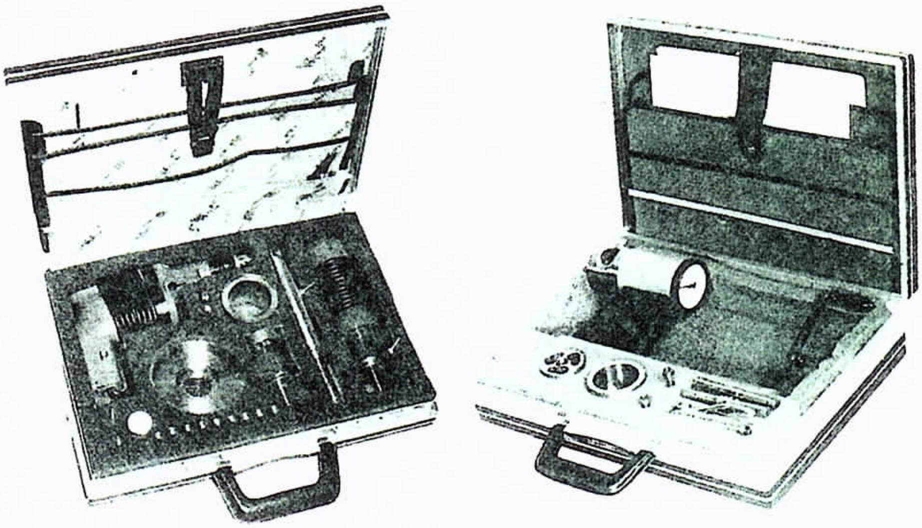


Figure 4. Capo-test equipment consisting of one suitcase with drill, undercutting and expansion insert device (left) and another with a lok-test pullmachine, model automatic.

REFERENCES:

[1] Kierkegaard-Hansen, P. (1975), "Lok-Strength", Nordisk Betong, issue 3, 1975, Denmark.

[2] Krenchel, H. (1970), "Lok-strength testing of concrete, Report no S 3/69", Structural Research Laboratory, Technical University of Denmark.

[3] Bellander, U. (1976), "Documentation of the strength of concrete in finished products", Swedish Cement and Concrete Research Institute (CBI), Technical University of Sweden.

[4] Johansen, R. (1979), "Curing conditions and in-situ strength development of concrete measured by various testing methods", Cement and Concrete Research Institute (FCB), Technical University of Norway.

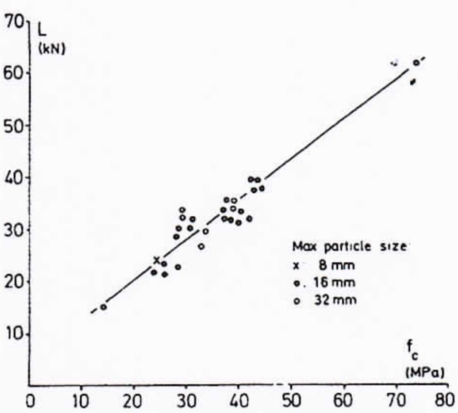


Figure 5. Lok-strength in kN pull-force relative to cylinder compressive strength in MPa.

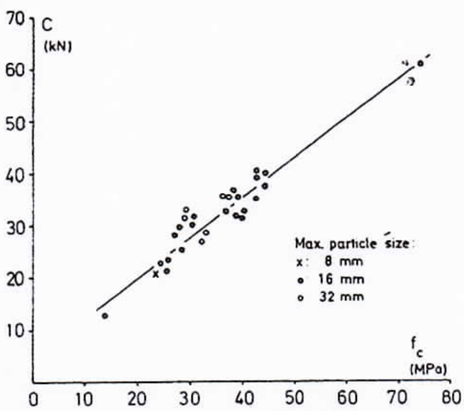


Figure 6. Capo-strength in kN pull-force relative to cylinder compressive strength in MPa.