Pull-out testing by

LOK-test and CAPO-test

with particular reference to the in-place concrete of the Great Belt Link

Storebælt

Appendix 2. Relation of pull-out force versus compressive strength

Theoretically, the LOK-test and the CAPO-test pull-out force may be transformed into the compressive strength of the concrete. This has been demonstrated by a finite element analyses, cf. [Ottosen, 1981]. The pull-out force was found to be proportional to the compressive strength of concrete. Thus, it is possible from a required compressive strength to calculate the corresponding pull-out force and to specify this force in kN-units instead of using cylinder measures.

Traditionally, the compressive concrete strength is measured on cast cylinders (dia. 150 mm, height 300 mm) as known from e.g. Denmark and North-America. However, such testing is not representing the true uniaxial compressive strength, but it indicates a practical measure of the compressive strength of concrete, accepted as a standard.

Before the failure mechanism of pull-out testing was investigated and understood, the practice was to conduct comparative measurements between the pull-out force of a concrete and the compressive strength of concrete cylinder or cube, in order to determine the relation between the two types of measurements.

This procedure was predominant from 1975 and 10 years onwards. The findings from a large number of comparative investigations are today available [Petersen, 1990]. The data substantiate the existence of one universal relationsship between pull-out force and compressive strength as measured on specimens (one relationship for cylinders and one for cubes) for any normal type of concrete.

It is also interesting to notice that the experimentally found relationship between the pull-out force and the compressive strength as measured on 150 mm dia., 300 mm height cylinders is in agreement with the findings of the theoretical element analyses, cf. [Ottosen, 1981].

In spite of the experience with the general relationship obtained so far, the user of the LOK-test and the CAPO-test system may still want to determine the correlation for one's »own special concrete mix«. At the planning and the execution of such a relationship it is important to observe a number of basic rules, otherwise the correct relationship will not be found.

To facilitate the planning of the trial and to ease the practical testing, the following pages describe the types of tests to be conducted and especially how they should be performed based on experience from many test series from Denmark as well from especially North-America, cf. [Krenchel, 1984] and [Bickley, 1982].

If the comparative experiment is conducted correctly, the same relationship is found for LOK-test and for CAPO-test no matter what type of normal concrete mixes to be investigated, cf. [Krenchel, 1982] and [Bellander, 1983)]. Concretes with maximum aggregate size of more than 38 mm have, however, not been investigated.

It should also be noticed that other relations than the »general one« will be found if lightweight concrete or pure mortar is investigated. This may be important when testing normal concrete, e.g. at the surface of a slab where separation has taken place during casting or consolidation. If the pull-out cone only consists of pure mortar, i.e. with no aggregates visible, an error may be introduced in the measurements by using the »general relationship«. The concrete strength will by means of pull-out testing transformed to concrete cylinder strength in this manner be evaluated too low.

One may only add, that the separation of the concrete is a fault (defect) which should have been prevented, and pull-out testing will clearly reveal it.

Choosing the test specimens

LOK-test and CAPO-test are sensitive test methods. Even small differences in the casting of the concrete, the compaction, the separation, the curing conditions and the maturity of the test specimens will entail significant influences on the relationship to be established. To eliminate such disturbing factors, the pull-out force and the compressive strength have, as a general rule, to be determined on specimens with identical concrete quality.

In Denmark the potential compressive strength is measured on cast cylinders with a diameter of 150 mm and a height of 300 mm, cf. DS 423.20, see figure 43. Consequently, the corresponding pull-out forces have also to be measured on 150 by 300 mm cylinders.

Cylinder compressive strength versus LOK-test pull-out force

A LOK-test insert is attached centrally at the steel mould bottom of a cylinder. This requires a 7 mm hole to be drilled centrally in the bottom, countersunk, for the LOK-test insert to be secured with a screw, cf. figure 44.

Experience has shown, that it is difficult to install a LOK-test insert at the top of a cylinder. If the insert is mounted in the lid, the insert has to be pressed into the concrete rather vertically. Such an operation may remove the aggregates from the failure zone of the pull-out cone, and the test will not be representative of the quality of the concrete of the cylinder.

On the other hand, investigations have shown [Bickley, 1981] that the strength of a correctly manufactured cylinder is not different from the bottom to the top. Thus, the positioning of the LOK-test insert at the bottom is the optimal.

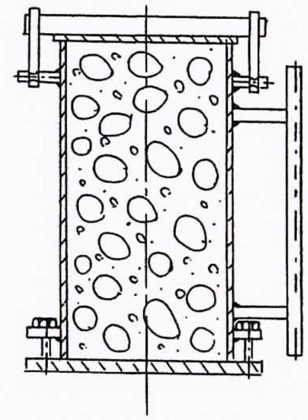
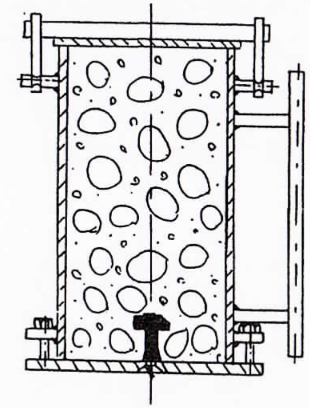


Figure 43. In Denmark the potential compressive strength is measured on cylinders, diameter 150 mm, height 300 mm. The cylinders have to be cast and compacted in steel moulds with DS 423.20 tolerances and cured in water at 20 °C until testing takes place according to DS 423.23.

Figure 44. A cylinder steel mould as shown in figure 40 is supplied with a LOK-test insert at the bottom. The cylinder is cast, compacted and cured as with normal cylinders (DS 423.21). pull-out testing and compression testing of the cylinder may then be performed on concrete with identical quality.



Retaining steel ring
The minimum distance from the center of a pull-out test to edges or corners has to be 100 mm. Otherwise severe radial cracking due to splitting of the concrete during pull-out testing may occur. This phenomenon is specially pronounced if the aggregates are rather hard or large or if the concrete strength is relatively high. The splitting of the specimen will lead to lower pull-out forces, while the influence on the cylinder strength only is moderate (for minor splitting cracking). Therefore, the splitting tendency has to be avoided.

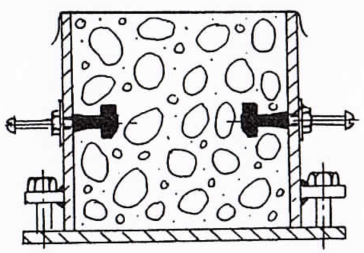
This is done by tigthening a retaining steel ring around the part of the cylinder where the pull-out testing has to be performed, illustrated in figure 47.

To create a strong and rigid connection between the the concrete and the steelring a quick setting rapid epoxy is applied between the two surface to eliminate any irregularity.

When tightening the retaining ring radial stresses will be introduced into the cylinder concrete bottom. Such stresses have no influence, however, on the values of the pull-out forces, cf. [Jensen, 1980].

Testing
According to DS 423.21 the cylinder has after casting to be placed horizontal in the mould with its slot upwards. This arrangement ensures among other

Figure 45. The smallest test specimen that fulfils the minimum distance requirement of 100 mm from the centre of the test to edges and corners is a 200 mm cube. The cube is supplied with two LOK-test inserts centrally placed on opposite vertical faces as shown. The remaining two vertical faces are used for pull-out testing by CAPO-test to be compared to the LOK-test.



things an uniform concrete quality throughout the cylinder.

Testing of the cylinder takes place at a required maturity. First the LOK-test is performed, then immediately afterwards the compression test is performed. The LOK-test is only performed »exactly to failure«, by which the pull-out cone is not pulled out. It should only be lifted 0.1mm to 0.5mm from the concrete surface. To ensure this small displacement, the LOK-test instrument is loaded just to failure and no further. When the peak-load has been reached and the pointer of the gauge has dropped 0.5 kN to 1.0 kN, the instrument is quickly unloaded.

At the compression test of the cylinder, the slightly dislodged cone will be pushed back into position, and the pull-out testing will have no influence on the cylinder compression test result [Bickley, 1982]. To check this finding, seperate cylinders should be cast without embedded LOK-test inserts and tested in parallel to the cylinders containing LOK-test inserts. All cylinders have to be cast identically at the same time from the same batch and vibrated simultaneously on the same vibration table to avoid one-sided errors.

For each cylinder, comparative measurements are found relating LOK-test pull-out force (in kN) to cylinder compression strength (in MPa). By testing at different maturity ages with equal strength gain throughout the entire strength range, the relation between pull-out force and cylinder compression strength may be determined by means of regression analysis.

LOK-test pull-out force versus CAPO-test pull-out force
The described procedure cannot be used for the estimation of the relationship between the CAPO-test pull-out force and the cylinder compressive strength, since pull-out testing by CAPO-test always will leave a fully dislodged cone hole and this cone hole will lower the cylinder compressive strength significantly even if attemps are made to fill-out the cone hole with a quick setting mortar before the compression test is performed.

Therefore, another procedure suggested by *H. Krenchel* [Krenchel, 1982] and used succesfully since then, has to be used. Here the LOK-test and the CAPO-test pull-out forces are measured on the same specimen. The specimen has to be as small as possible and it needs to have plane surfaces. Keeping the minimum distance of 100 mm between the centre of a pull-out test and the edge or corners in mind, the only specimen that fulfils such requirements is a 200 mm concrete cube.

Properly cast and vibrated on a vibration table such cubes have been found to have equal LOK-test and CAPO-test pull-out forces at the vertical faces centrally placed [Krenchel, 1982], [Bellander, 1983] and [Bungey, 1983].

Thus, two LOK-test inserts are placed in the steel mould through 7 mm centrally placed holes at opposite vertical faces, cf. figure 45. The two remaining vertical faces are used for pull-out testing by CAPO-test.

When testing the 200 mm cubes at the same horizontal layer with LOK-test and CAPO-test a slightly higher variation of the pull-out results is usually found compared to the variation of the LOK-test results performed at the bottom of the cylinders. The reason is, it is believed, that it is more difficult to make homogeneous cubes than cylinders.

Test program in general

Consequently the following test specimens are needed to conduct a proper relationship program:

- Test cylinder, $d \times h$ = 150×300 mm, according to DS 423.20, cast in minimum three equal sized layers of concrete in the steel mould, fastened to and vibrated on a vibration table following DS 423.21 and tested in compression according to DS 423.23. This type of concrete specimen is named »type A specimen«, cf. figure 43.
- Test cylinder, $d \times h$ = 150×300 mm, according to DS 423.20, with one LOK-test insert attached through an undersunk 7 mm hole at the bottom, cast in minimum three equal sized layers of concrete in the steel mould, fastened to and vibrated on a vibration table following DS 423.21. The cylinder is tested by LOK-test at a desired maturity, exactly and just to failure according to DS 423.31 with attached retaining steel ring around its end. Immidiately afterwards, the cylinder is tested in compression according to DS 423.23. This test specimen is named »type B specimen«, cf. figure 44.
- Test cube 200 mm mounted with two LOK-test inserts centrally placed at two opposite vertical faces of the steel mould through 7 mm holes, cast in three layers in the steel mould, fastened to and vibrated on a vibration table. The cube is tested at a desired maturity first by CAPO-test centrally placed on the vertical faces not containing LOK-test inserts, and secondly with LOK-test on the remaining vertical faces. This test specimen is named »type C specimen«, cf. figure 45.

Testing at different maturities

The testing of the specimens has to take place so that the clusters of comparative measurements are distributed approximately with equal distances throughout the strength range. This may be obtained by testing the specimens at 1, 2, 3, 7, 14, 28 and 35 maturity days.

To obtain a resonable certainty of the slope of the correlation, it is desirable to have at least a 40 MPa span of the total strength range [ACI, 1989]. For a concrete with a *w/c*-ratio of 0.4 such a span should be obtained if it is tested at maturities as above mentioned.

Number of tests

Each cluster of observations should contain a minimum of three corresponding values to achieve the needed statistical accuracy [ACI, 1989]. Consequently the following numbers of test specimens are needed as a minimum:

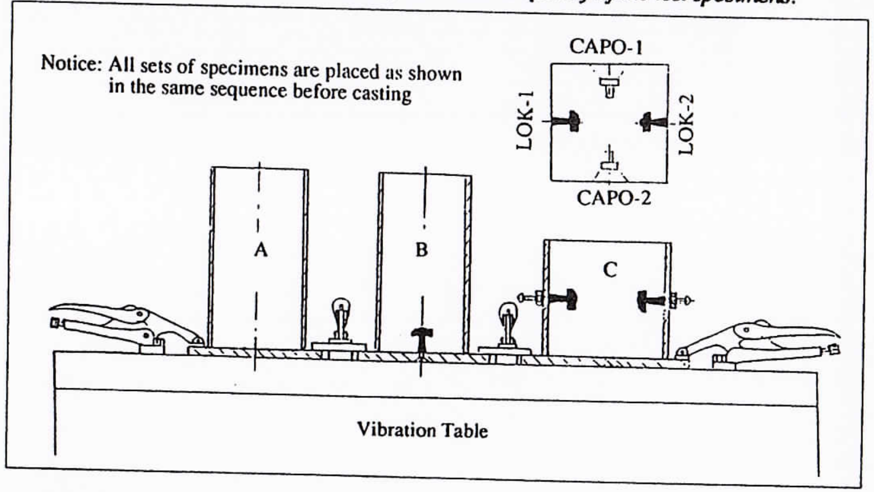
- 21 type A specimens, i.e. cylinders without LOK-test inserts, cf. figure 43.
- 21 type B specimens, i.e. cylinders with LOK-test inserts, cf. figure 44. Each cylinder is supplied with one LOK-test insert at the bottom.
- 21 type C specimemns, i.e. cubes with LOK-test inserts, cf. figure 45. Each cube is supplied with two LOK-test inserts at two opposite vertical faces, centrally placed.

For verification of the compression machine used, 20 cylinders are cast seperately according to DS 423.20 and DS 423.21. Half of them are tested on the compression machine used for testing of type A and type B specimens, and the remaing half is tested in parallel on an authorized laboratorys compression machine. The testing takes place at 3 and 28 maturity days.

Detailed description of the relation program

In the previous material the background of the relationship program and the required minimum number of test specimens are advised. In the following a

Figure 46. The test specimens are manufactured in sets of three identically in the same manner besides eachother (type A, type B and type C specimens), compacted at the same time on the vibration table and cured in water at 20 degree centigrades until the required maturity has been obtained before testing. The LOK-test and the CAPO-test pull-out forces are very sensitive to the variations of the concrete quality of the test specimens.



detailed description of the program is given.

How to manufacture the test specimens

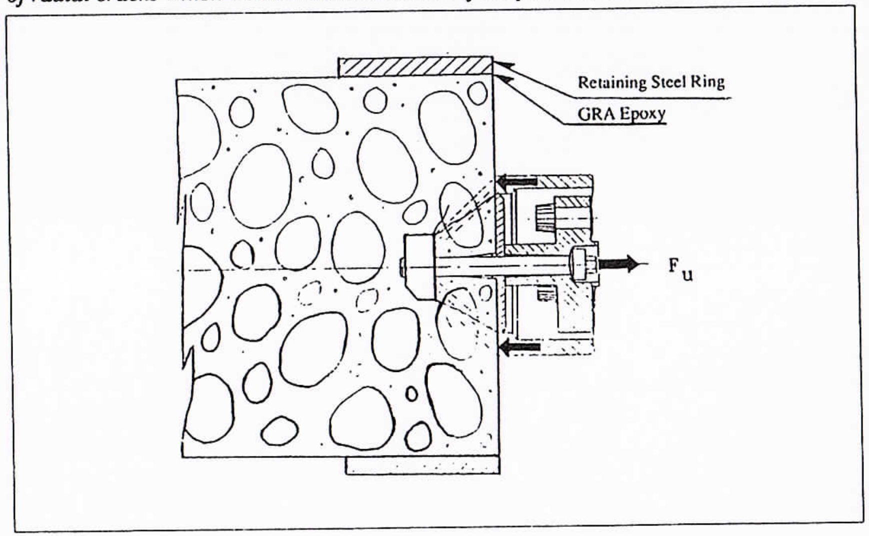
A vibration table is needed with sufficient space for one cylinder mould type A, one cylinder mould type B and one cube mould type C. The moulds, all in steel, have to be clamped to the table as illustrated in figure 46. To fasten the moulds to the table with clamps, 10 mm bolts have to be welded to the table for connection to 10 mm nuts and washers.

A batch is made containing approximately 450 liter of concrete and transported to the laboratory. The concrete has to be stirred continously. If the air content changes due to pumping on-site, the same pumping technique should be applied to the concrete before casting of the specimens.

One set of test specimens as illustrated in figure 46 is produced in the following manner:

- From the batch the three moulds, type A, type B and type C, attached to the vibration table are filled one third with concrete. Vibration takes place until a thin layer of mortar covers all aggregates and no more air is released.
- Another one third of concrete is filled into the moulds followed by vibration as described above.
- Finally the moulds are filled out with concrete and vibrated. The cylinder lids are twisted in-place and tightened to the cylinders. The free surface of

Figure 47. A 150 mm diameter test cylinder needs a strong clamp to prevent formation of radial cracks which would reduce the value of the pull-out load.



the cubes are planed and smoothened.

- The three specimens in each set are marked with identification codes on watertight stickers attached to the steel moulds, from 1A; 1B; 1C to 21A; 21B; 21C respectively. The figure indicates the number of sets and the letter the type of specimens.

Instead of filling the specimens by three layers, it may be decided to fill them in two layers (permitted by the Danish Standard). If the two-layers-filling is selected, it is advised to fill the cubes so the LOK-test inserts are fully covered by concrete and not splashed by cement paste, vibrate, and then fill the cube to the top and repeat the vibrating.

This process is reiterated 21 times, giving a total number of 63 specimens of which 21 are type A specimens, 21 type B and 21 type C specimens.

From another batch containing approximately 150 liter of concrete 20 cylinders, $d \cdot h$ = 150·300 mm, are manufactured according to DS 423.21. The cylinders are produced in pairs clamped to the vibrations table; cast, vibrated and supplied with lids as mentioned above. Each pair of cylinders is marked with waterproof stickers labelled 1D; 1E to 10D; 10E.

How to cure the specimens

The curing of the specimens takes place as follows:

- The top surfaces of the cubes are wrapped up in a watertight and close-fitting plastic film directly after casting.
- The cubes are immediately after the above mentioned preparation has been finished placed in a temperature controlled waterbath at 20 degree centigrades together with the cylinders. It is presumed that the cylinder steel moulds are of a watertight type. The cubes are placed vertical as cast, while the cylinders are placed horizontally with the cylinder slot upwards.
- After 24 maturity hours the specimens are taken out of the bath. All screws connected to the inserts are removed and the steel moulds are removed from the specimens. All concrete specimens are marked clearly with watertight stickers with the same ID-number as indicated on the steel moulds. Then the specimens are placed back into the waterbath at 20 degree centigrades.

How to finally mark the specimens

Three sets of specimens, each consisting of type A, type B and type C specimens, are chosen at random from the 21 sets in the waterbath after respectively 1, 2, 3, 7, 14, 28 and 35 maturity days. The three sets are marked with the maturity of the concrete. In this manner each test specimen at this stage has a marking indicating:

- Days of maturity when tested, number of set, type of specimen. A marking as e.g. 1-17-C shows the specimen to be one day old at 20 degree centigrades at the time of testing, the specimen is from set number 17 and is a cube with two LOK-test inserts.

How to perform the testing

Well ahead of the time of testing, the LOK-test instrument is calibrated as well as the laboratory compression machine. Both the LOK-test and the CAPO-test equipments are cleaned, adjusted and the checklists are filled out and signed.

Whenever the test specimens have achieved the required maturity, three sets of specimens, each consisting of one type A, B and C specimens are chosen at random and tested as follows:

Test specimens type A and type B

The three cylinders type B are first tested by LOK-test at the bottom. On the cylinder circumference where the LOK-test insert is located a thin layer of quick setting epoxy is applied. While still wet, the steel retaining ring is tigthened around the end. A plastic wrap may be placed in between to avoid adhesion to the steel ring. The epoxy has to flow out all along the circumference of the ring-cylinder surface connection. Surplus epoxy is removed. The epoxy has to harden. Usually it takes 5 minutes for a quick setting epoxy at 20 degrees centigrade.

Pull-out testing with LOK-test takes place exactly and only to failure as shown in figure 47. The pull-out cone must not be lifted more than 0.1 to 0.5 mm from the testing surface after testing has been completed. This is ensured in the following manner. When the gauge pointer of the instrument during loading has reached the peak-load and fallen back 0.5 to 1.0 kN, the instrument is quickly unloaded. For the experienced technician the cone failure will hardly be visible.

The instrument and the attachment parts to the cast-in disc are removed together with the steel retaining ring. The bottom surface where the testing has been performed is inspected for any radial cracking and, if visible, made clearly visible by means of a speed marker. A photo is taken of the cylinder end with ID-number attached and the type of failure is recorded together with the value of the pull-out force.

After each set of type B specimens have been tested with LOK-test they are tested in compression together with the three type A cylinders. The types of compression failures are recorded along with the compression results.

Figure 8 and 48 illustrates the possible types of LOK-test failures loaded exactly to failure and the types of compression failures.

Test specimen type C

The three cubes at each maturity date are then tested as follows:

Figure 48. Characteristic types of cylinder compression failures.

Failure type a *is the normal type of failure. The cylinder has cone-shaped failures at the ends of the cylinder (sliding failures) where the compression plates have been located. This type failure is acceptable.*

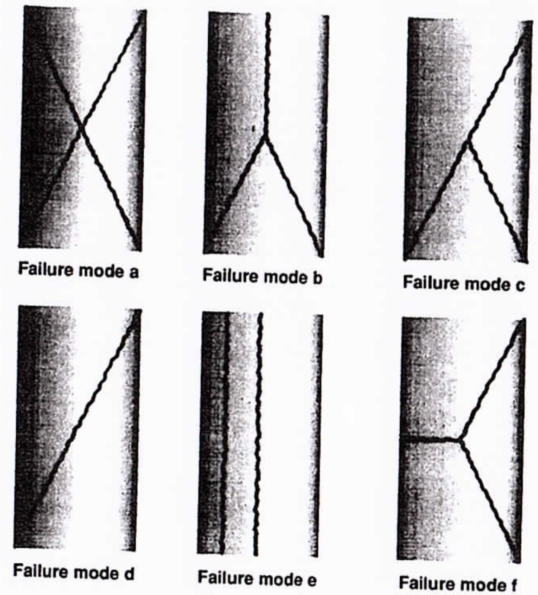
Failure type b *is composed of a sliding failure (cone-shaped, cf. type a) below and a separation failure at the top, cf. type e. Separation takes place due to relative small friction between the compression steel plate and the cylinder compared to a cone failure where the friction is relatively larger. This type of failure is acceptable.*

Failure type c *is a failure composed by a diagonal sliding failure (cf. type d) and a cone shaped failure (cf. type a). This type of failure is acceptable.*

Failure type d *is called a diagonal sliding failure. This type of failure is acceptable.*

Failure type e *is a regular separation failure. This type of failure is acceptable.*

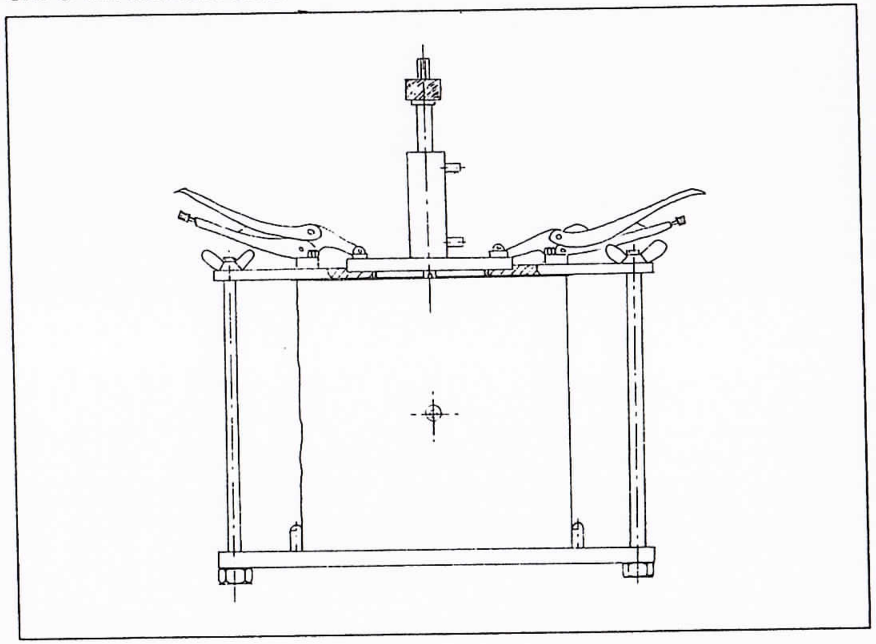
Failure type f *consists of separation failure perpendicular to the cylinder axis and tendency to cone-shaped failures to the other side. This type of failure is typical of test cylinders with an excentric load. This type of failure is **not** acceptable.*



- First the LOK-test inserts are tested, again accurately and just to failure. This is to make sure the pull-out testing by LOK-test is not influencing the subsequent pull-out testing by CAPO-test. The LOK-test failures, cf. figure 8, are registrated. If visible radial cracking turns up, they are illustrated by means of a speed-marker and photo-registered along with the ID-number. The pull-out forces are recorded.
- Pull-out testing by CAPO-test is performed on the remaining vertical faces, centrally placed. The CAPO-test suction plate is secured to the to the face of the cube by means of a testing rig as outlined in figure 49. The suction plate controls the proper execution of the drilling of the centerhole, the planing of the surface and the routing of the recess with the diamond tools supplied in the CAPO-test kits.

The suction plate with the test rig is removed and the CAPO-test expansion unit inserted in the hole and expanded fully. pull-out testing with CAPO-test is

Figur 49. The 200 mm cube mounted with the suction plate centrally placed on one of the vertical faces not containing a LOK-test insert. The suction plate is kept in-place by means of a test rig. The suction plate controls the drilling of the centre hole, the planning of the surface and the recess routing with the CAPO-test diamond tools.



performed, the peak-load recorded and the cone fully dislodged.

The type of CAPO-test failure is recorded, cf. figure 10. If radial cracking has turned up, the cracking is made visible by means of a speed-marker and photo-registered along with the ID-number.

Test specimens type D and E
Each 10 cylinders of type D and E are in pairs divided in two groups with 5, at random. One group (5 sets of type D and type E) is tested at 3 maturity days, the D types on the compression machine used in the laboratory, and the E type on an authorized testing laboratory testing machine. The remaining cylinders are tested similarly at 28 maturity days. All types of cylinder failures are recorded.

Filing of the specimens
The specimens are kept at the laboratory, pending further investigations. The test specimens, including drilled out cores (for CAPO-test) and pull-out cones are kept in air- and watertight plastic bags, marked clearly and systematically with the ID-numbers.

Interpretation of test results

The following data are now available:

- 21 compression test results from the cylinders type A and matching types of failures
- 21 compression test results from the cylinders type B and matching types of failures together with 21 LOK-test pull-out forces with matching types of failures
- 42 values of LOK-test and CAPO-test pull-out forces from testing of the cubes type C with matching failure types
- 5 compression test results from cylinders type D (lab compression machine) and 5 from cylinders type E (authorized lab compression machine) at 3 maturity days with matching types of failures
- 5 compression test results from cylinders type D (lab compression machine) and 5 from cylinders type E (authorized lab compression machine) at 28 maturity days with matching types of failures

The data have to be used for answering the following three main questions:

- What is the relationship between the cylinder compression strength and the LOK-test pull-out force?
- What is the relationship between the LOK-test and the CAPO-test pull-out forces?
- Is the laboratory testing machine reliable?

Before the questions may be answered, the data has, however, to be evaluated and accepted.

Evaluation of failure modes
Non-acceptable types of failures may occur, even if the technician is highly skilled and conducts the testing carefully.

Evaluation of the cylinder failure modes
The test result is rejected if the cylinder shows signs of eccentric loading resulting in horisontal splitting, failure type *f* of figure 48.

A correctly functioning and calibrated compression machine fulfilling the requirements of DS 423.23 will not cause such an eccentric loading unless the compaction of the cylinder has been performed inadequately.

Evaluation of the LOK-test failure modes
As shown in figure 8 the only acceptable failure is the type *x* failure. If the *y* and/or the *z* type failure modes appears, the test result is rejected.

Evaluation of the CAPO-test failure modes
Similarly, only the type *x* failure of figure 10 is acceptable. If failure modes of the types *y* or *x* emerges, the test is rejected.

The relation between the LOK-test pull-out force and the compressive strength
Before the relation can be found, it has first to be evaluated wheather or not the LOK-test insert tested at the cylinder bottom (type B specimen) has had any influence on the subsequent compression testing of the cylinder. Secondly, it has to be demonstrated, that the compression machine used provides statistically the same results as when using the compression machine of the authorized laboratory.

Compressive strength of type A and B specimens
Related and accepted values of the compression testing of type A and type B cylinders are plotted against eachother in a diagram.

If, as normally found, the relationship between the two sets of measurements is not significantly different from 1.00, the values plotted have to be close to the 45 degree line of the diagram. This may be seen directly, or a linear regression analysis may be applied.

Compressive strength of type D and E specimens
The average of the five cylinder compression test results and the deviation at 3 maturity days are calculated when using the testing machine (type D specimens) in the laboratory and compared to the matching results from the testing machine (type E specimens) of an authorized laboratory. Similarly the results

are compared at an age of 28 maturity days.

The comparative results should not differ significantly.

LOK-test pull-out force versus compressive strength
If the pull-out testing with LOK-test is shown to have no significant influence on the cylinder strength when testing test specimen type B and the compression testing machine of the laboratory gives the same results as that of the authorized laboratory, the calibrated LOK-test pull-out forces of the type B specimens may be plotted in a diagram relative to the matching cylinder compression test results for each cylinder type B.

Earlier investigations have shown that this relationship consists of two straigth lines; one for pull-out force less than 25 kN and one for pull-out forces ranging between 25 kN and 60 kN. Based on this hypothesis, a linear regression analysis may be applied to the data to establish the best fitting relationship.

The relationship found is compared to the international determined and recognized one:

$$F_u = 0.96 \cdot f_c + 1.00 \qquad \text{for } 2\text{ kN} \le F_u < 25\text{ kN}$$

$$F_u = 0.80 \cdot f_c + 5.00 \qquad \text{for } 25\text{ kN} \le F_u < 60\text{ kN}$$

where F_u is the calibrated LOK-test pull-out force in kN and f_c is the calibrated cylinder compression strength in MPa.

When comparing ones own relationship to the above mentioned it should be noticed that the international determined relationship is based on a large number of measurements [Krenchel, 1984], while the just established relationship is determined only from a limited number of comparative tests. If no significant difference is found, the international established relationship should be applied.

LOK-test pull-out force versus CAPO-test pull-out force
For each cube the average of the pull-out forces of the two LOK-test inserts is compared to the average of the pull-out forces of the two CAPO-test inserts in a diagram. In case there is no significant difference between the the two types of pull-out tests, the plotted values should be close to the 45 degree line of the diagram. As mentioned before, the deviation of the pull-out test results measured on 200 mm cubes usually is slightly higher than if cylinders bottoms are tested.

If no significant difference is found between the pull-out forces, the established relationship between LOK-test and cylinder compression strength also applies for CAPO-test.

If a significant difference is found, the relationship between CAPO-test pull-out force and the cylinder compressive strength is established by substituting the LOK-test pull-out force with the pull-out force of the CAPO-test. ■

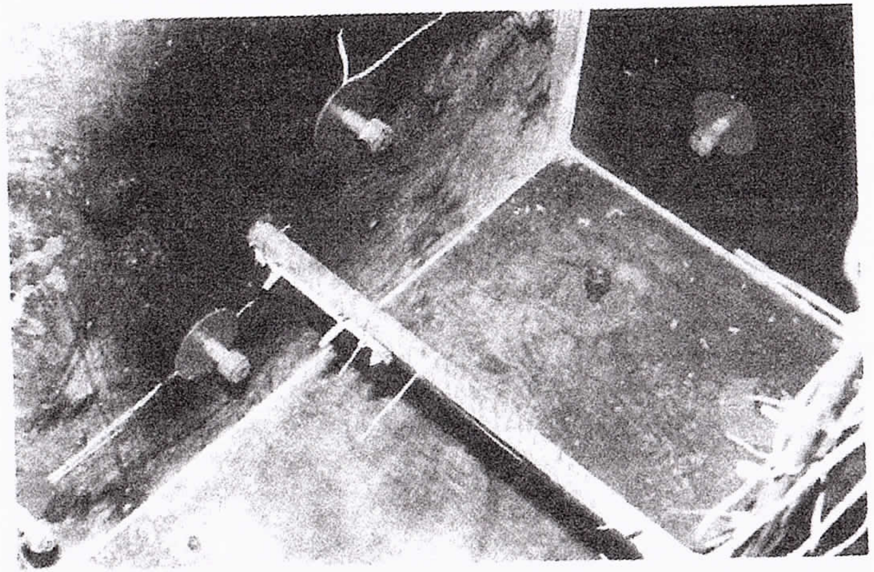


Figure 50. LOK-test inserts installed in a 900×900×500 mm mould for pre-testing the concrete according to SAB-III clause 4.5.3.1 Strength.

Figure 51. pull-out testing by LOK-test and CAPO-test carried out on a 200 mm concrete test cube.