CAPO-TEST pullout testing
(ASTM C900 [1)] and EN 12504-3 [2)])
on Shotcrete

Procedure and
On-Site Testing Examples

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CAPO-TEST PROCEDURE ON SHOTCRETE

After locating reinforcement the test position is chosen in the center of the reinforcement mesh.
Coring with a water cooled 18.4 mm diamond coring bit takes place to full 70 mm depth of the coring bit.
Minimum reinforcement spacing and depth, page 6

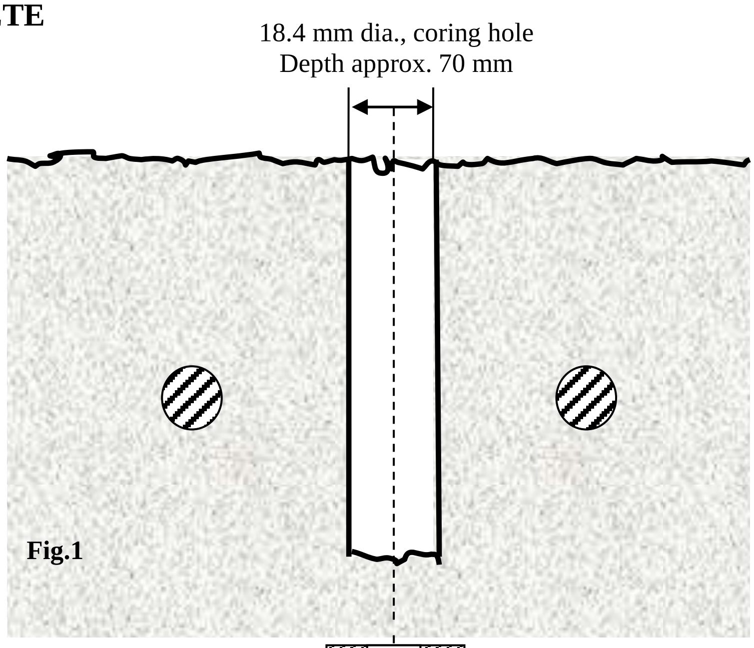


Fig.1

The centering brass rod is inserted in the hole and the diamond planning wheel is centered on the rods top. Planning takes place water cooled by pressing the units axel connected to the drill machine against the surface, which has to be plane in its total circumference. The parts are removed

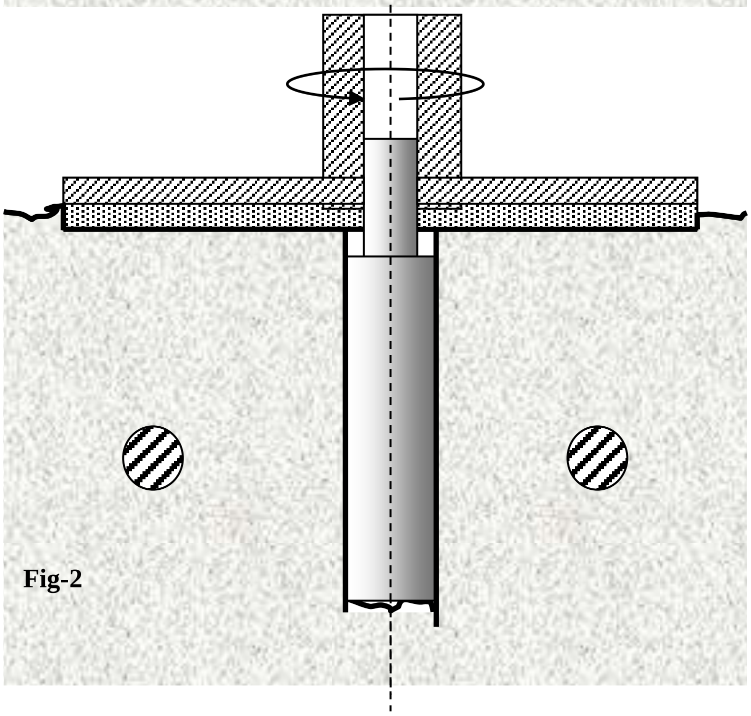


Fig-2

The diamond recess router shown above is inserted in the drilled hole and turned on. The bit is water cooled. The flange of the recess router has to rest firmly against the planed surface

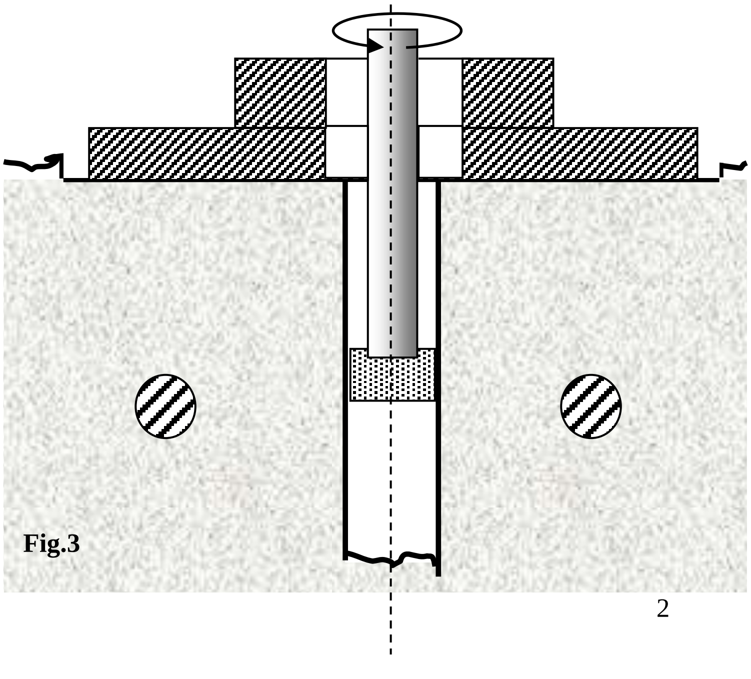


Fig.3

Recess routing takes place by pressing the flange of the router against the planed surface and moving it sidewards in bigger and bigger circles until the recess router shaft follows the side face of the cored 18.4 mm hole.
Notice the position of the operators fingers.
The diameter of the recess has to be 25.4 mm ± 0.2 mm after routing and the depth to the recess 25 mm.

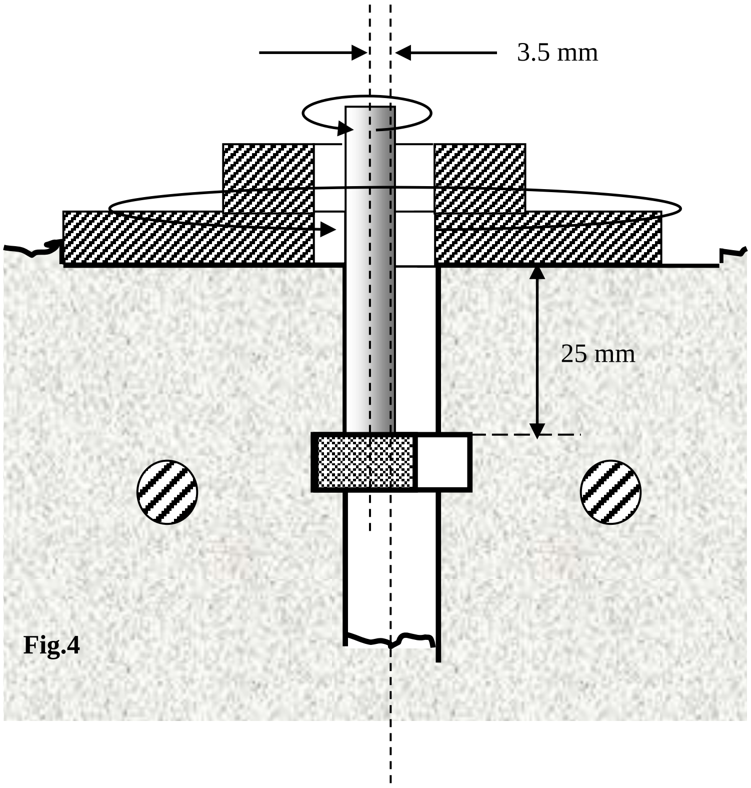


Fig.4

The assembled expansion tool with installed CAPO ring (above) is inserted in the hole and expansion of the ring takes place as shown below by turning the big nut to fully expanded position of the ring while keeping the center pull bolt in the same position. The cone pull bolt will be pulled against the CAPO ring, which will unfold in the routed recess.

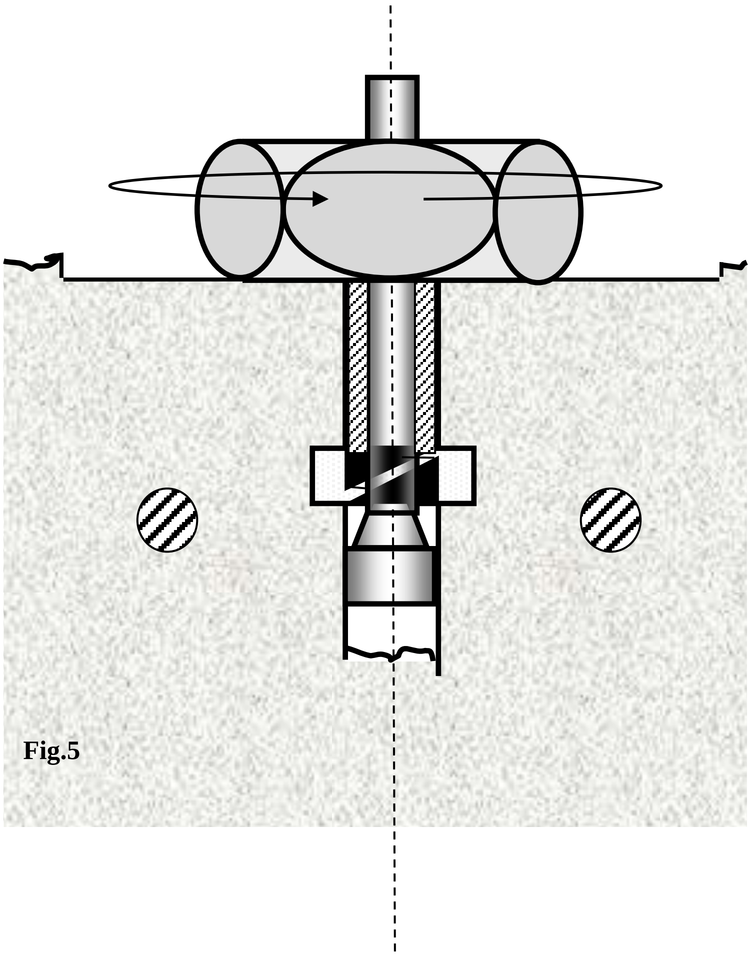


Fig.5

After fully expansion of the CAPO ring in the routed recess the counter pressure is installed on the surface and the coupling threaded to the center pull bolt

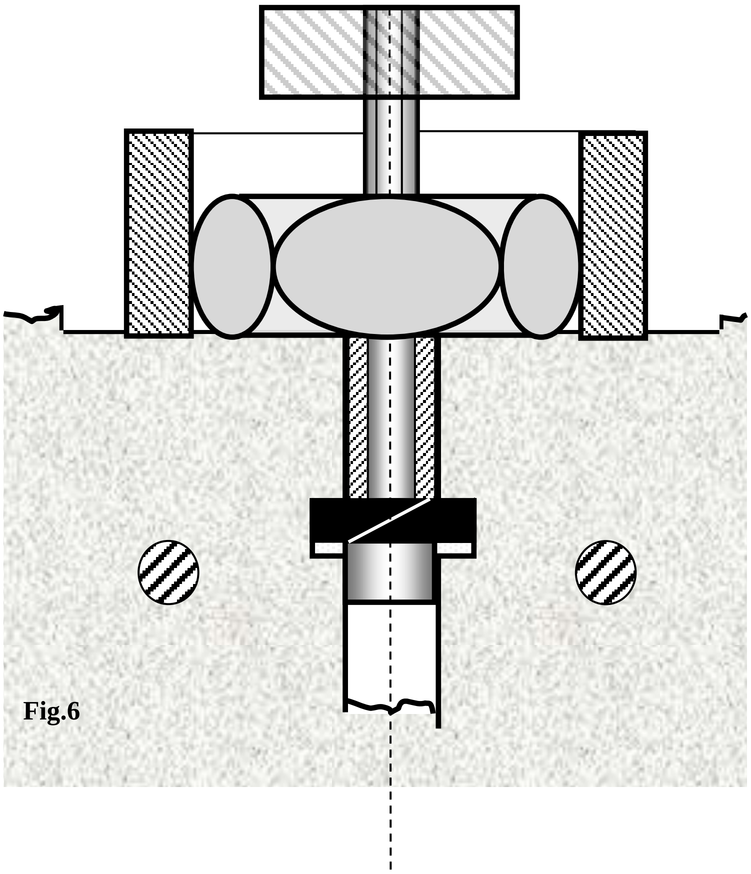


Fig.6

The hydraulic CAPO-TEST instrument is coupled to the coupling and the slack removed between instrument and counter pressure. Loading takes place by turning the instruments handle slowly.

During pullout compression forces are formed in a strut between the expanded ring and the counter pressure on the surface. This is why the pullout force correlates very well to compression test made on standard specimens.
At the end of the test a sliding failure is formed between the outer edge of the expanded ring and the inner edge of the counter pressure.

The maximum load in kN is recorded by the instrument and correlated to standard compressive strength of e.g. cylinders.

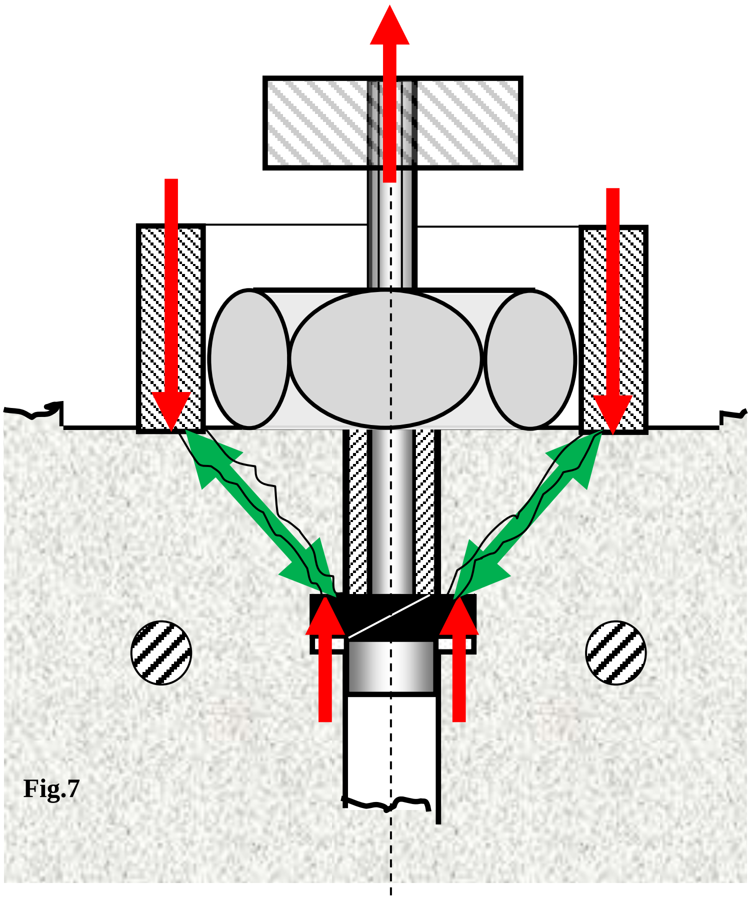


Fig.7

The completed CAPO-TEST.
Notice the unfolded CAPO ring on the cone pull bolt.

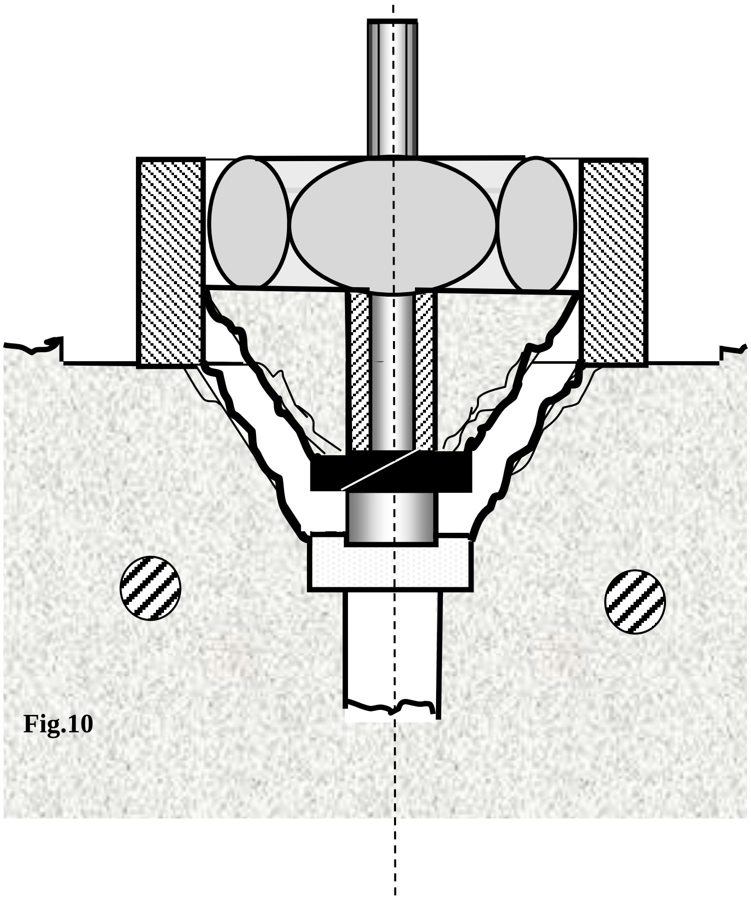


Fig.10

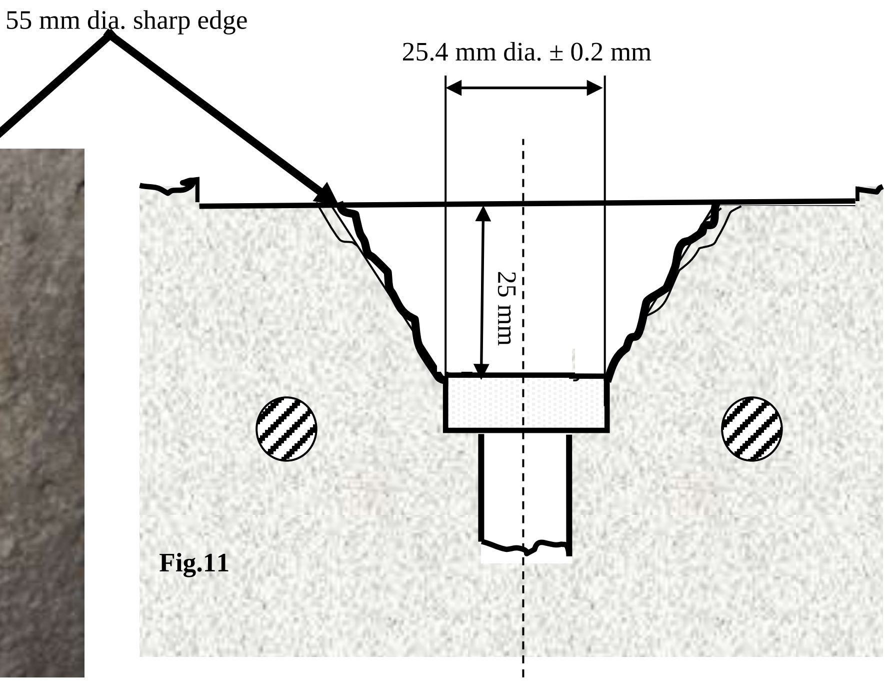


Fig.11

CAPO-TEST failure.
The criteria's for correctly performed testing:

1. Sharp 55 mm in diameter edge (no spalling on the planed surface) from the inner edge of the counter pressure
2. Routed recess diameter 25.4 mm ± 0.2 mm
3. Depth to the recess 25 mm from the planed surface

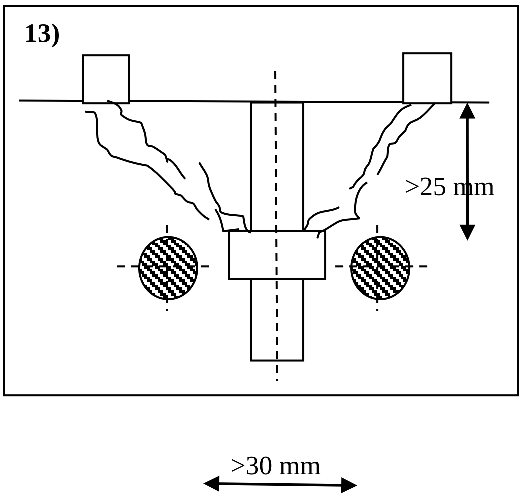
Test results in above example: 29.5 kN, 30.5 kN, 28.2 kN, 27.9 kN, 28.4 kN and 31.6 kN, shotcrete 4 weeks old

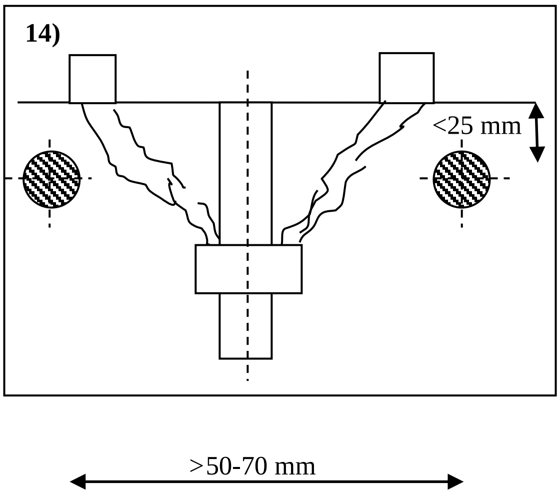
Capo-Test failure on shotcrete with steel fibers, **fig. 12**
Test results: 43.0 kN, 44.9 kN and 42.0 kN, shotcrete 5 weeks old

Reinforcement spacing and the depth of reinforcement:

The compression strut in fig. 7, page 4, is narrow for shotcrete with smaller aggregates
Reinforcement has to be outside the strut for the pullout force not to be affected by rebars, meaning:

1. For a depth of reinforcement larger than 25 mm the test has to be positioned in the middle of the reinforcement mesh with a minimum spacing of 30 mm, fig. 13)
2. For a depth of reinforcement less than 25 mm the test has to be positioned in the middle of the reinforcement and the spacing has to be minimum 50-70 mm, depending on the depth, fig. 14)





Correlations to 150 mm x 300 mm cylinder strength

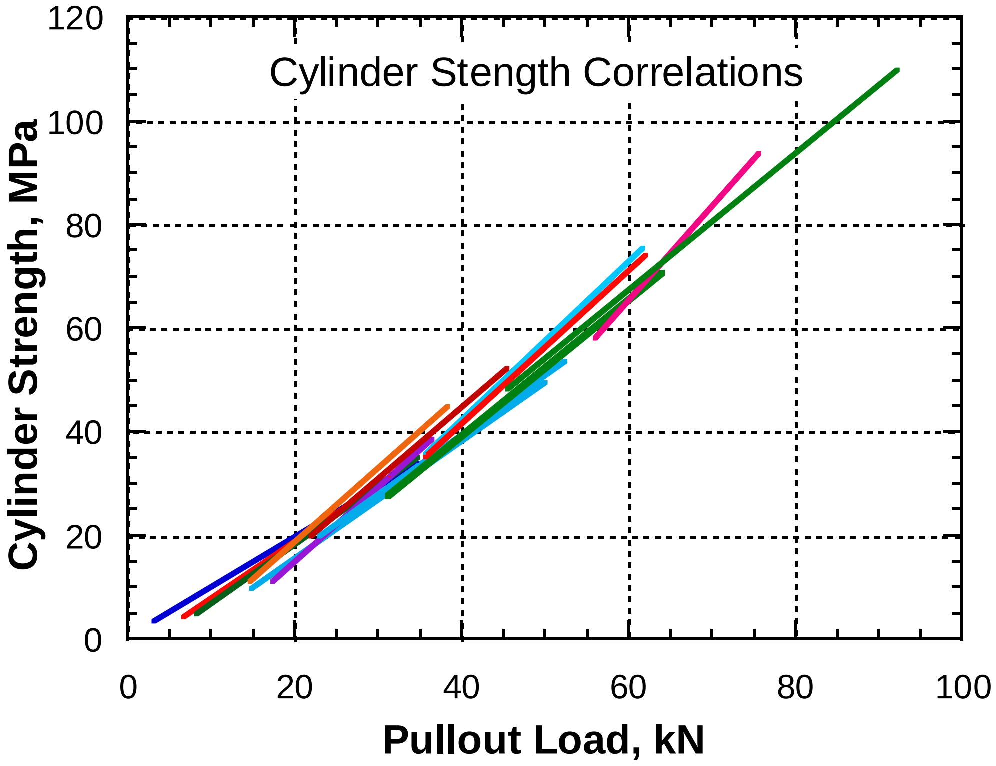


Fig 15)

Twenty major correlations between LOK-TEST / CAPO-TEST in kN and standard cylinder 150 mm x 300 mm compressive strength in MPa performed from 1982 to 2010
Ref (3), (4) and (5)

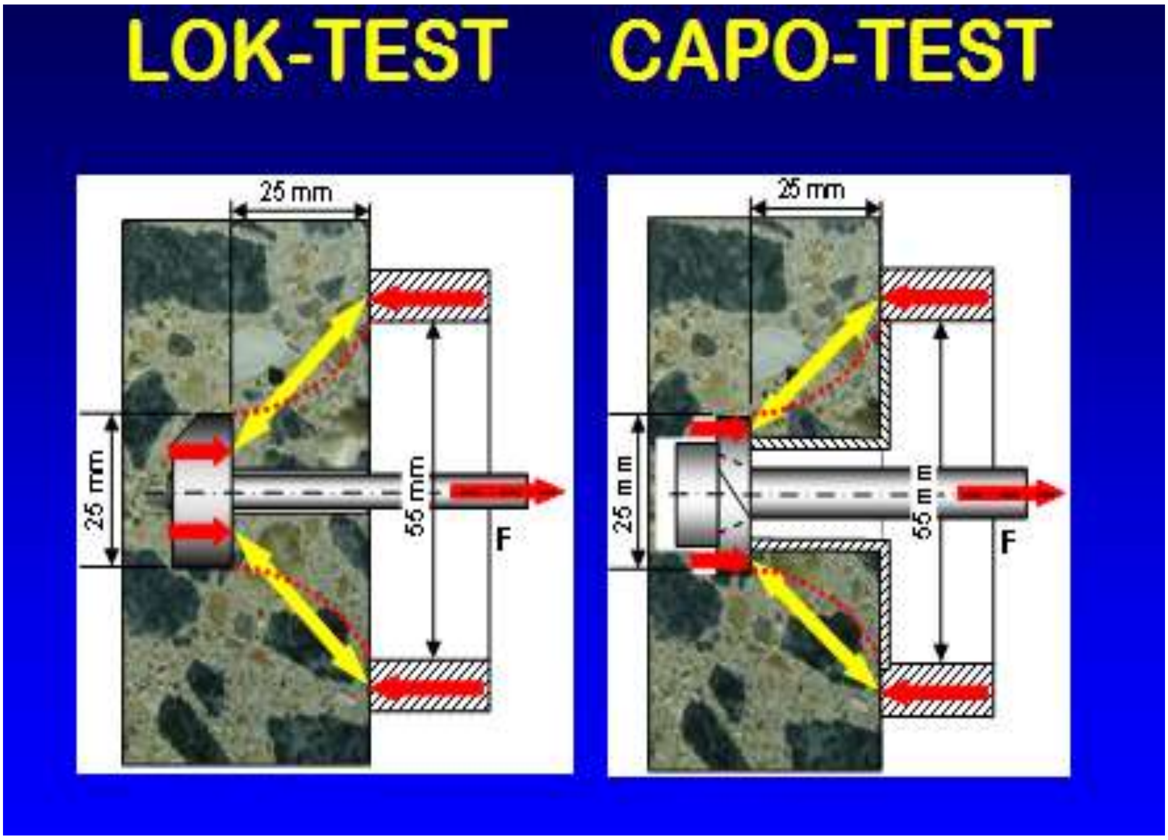


Fig. 16)

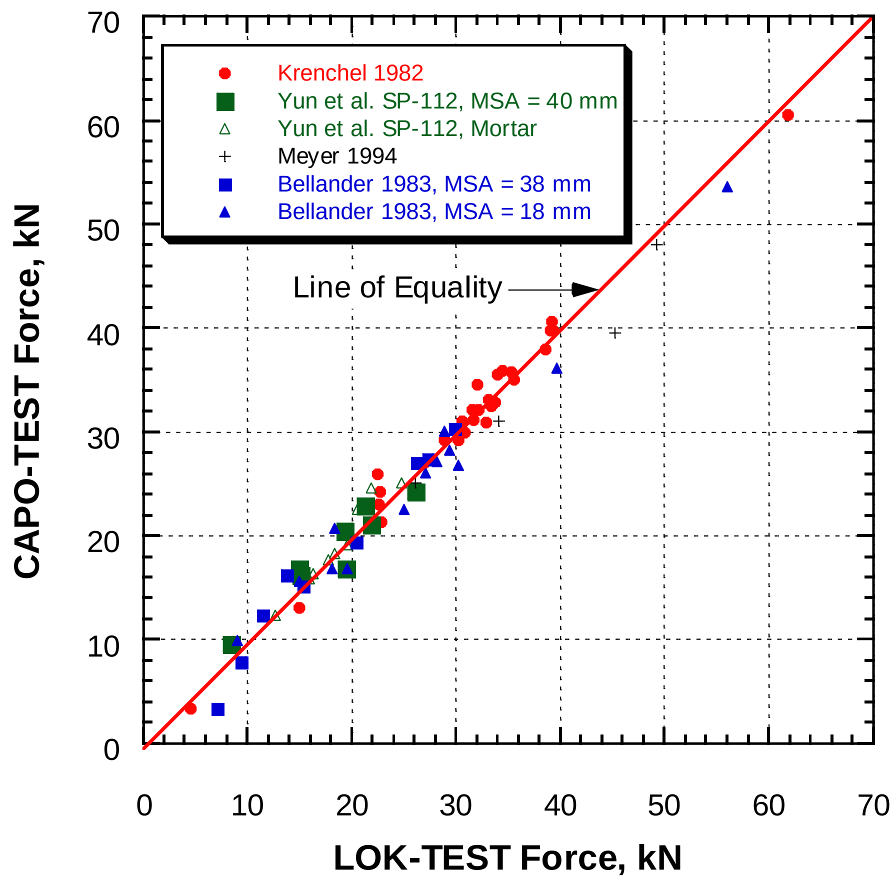


Fig.17)

Relationship between LOK-TEST and CAPO-TEST Ref (3) and (4)

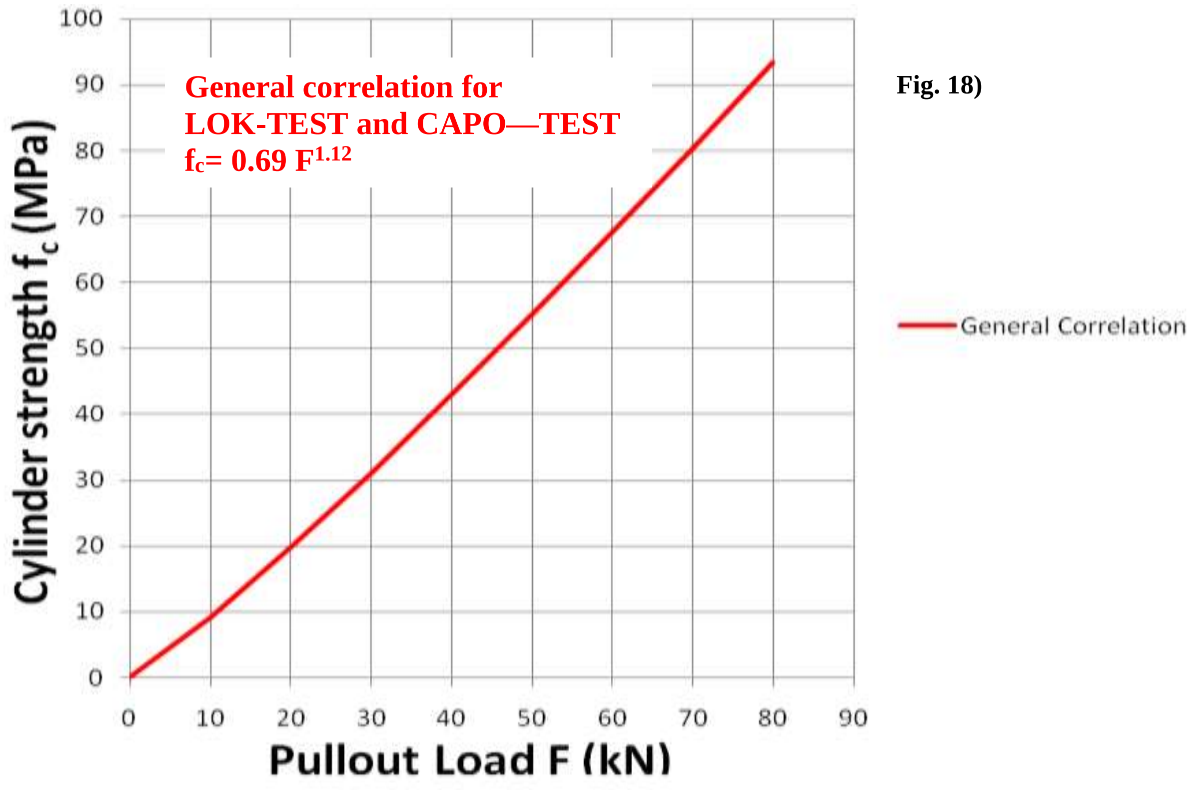


Fig. 18)

Examples of Correlations made for maximum aggregate size less than 6 mm (as with shotcrete)

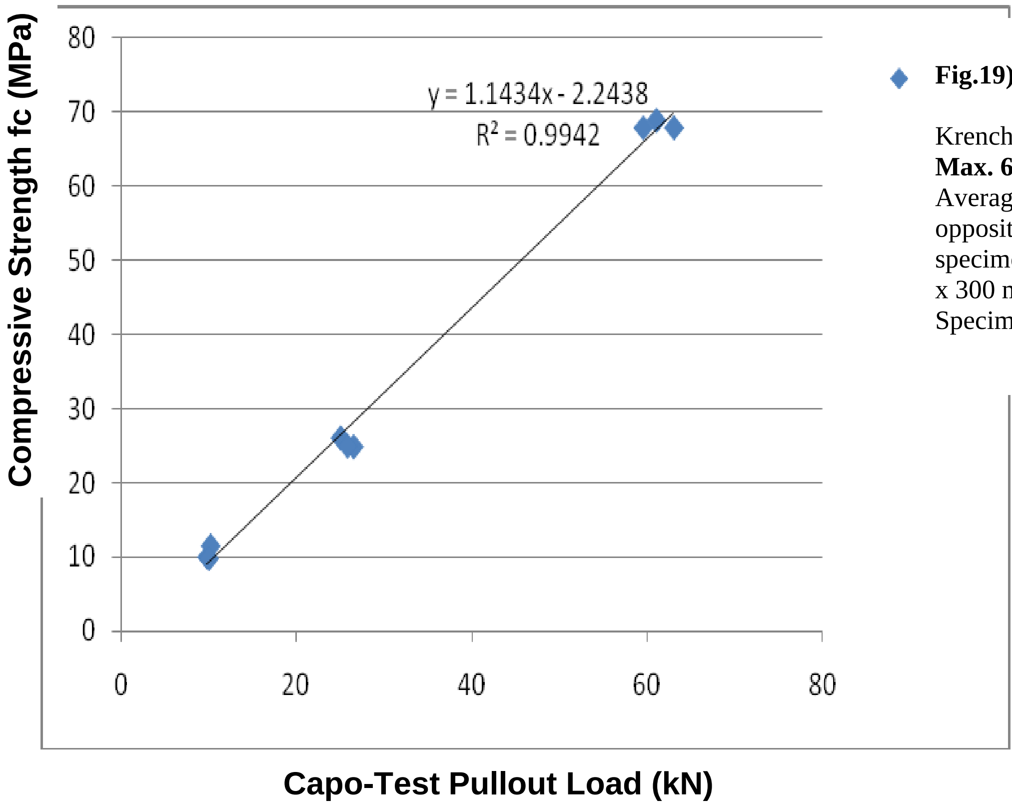


Fig.19)

Krenchel, 1982, ref. (4)
Max. 6 mm aggregate size
Average of 2 CAPO-TEST performed on opposite vertical faces on 200 mm specimens compared to cylinders (150 mm x 300 mm).
Specimens water cured and fully hardened

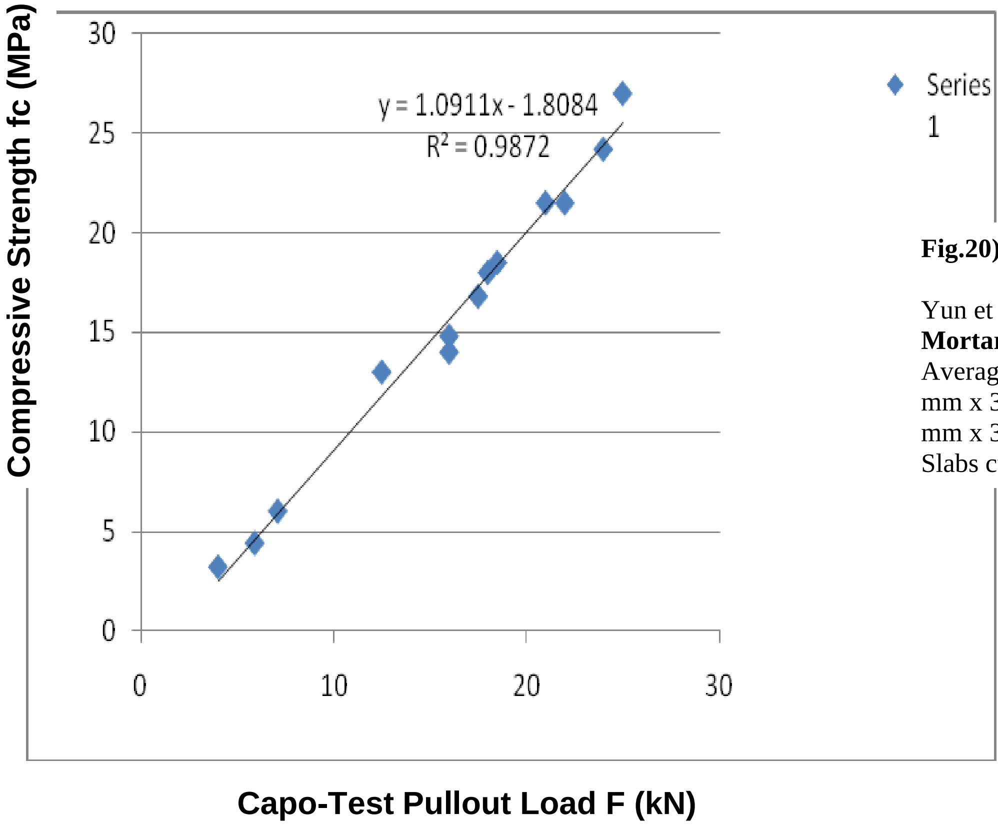
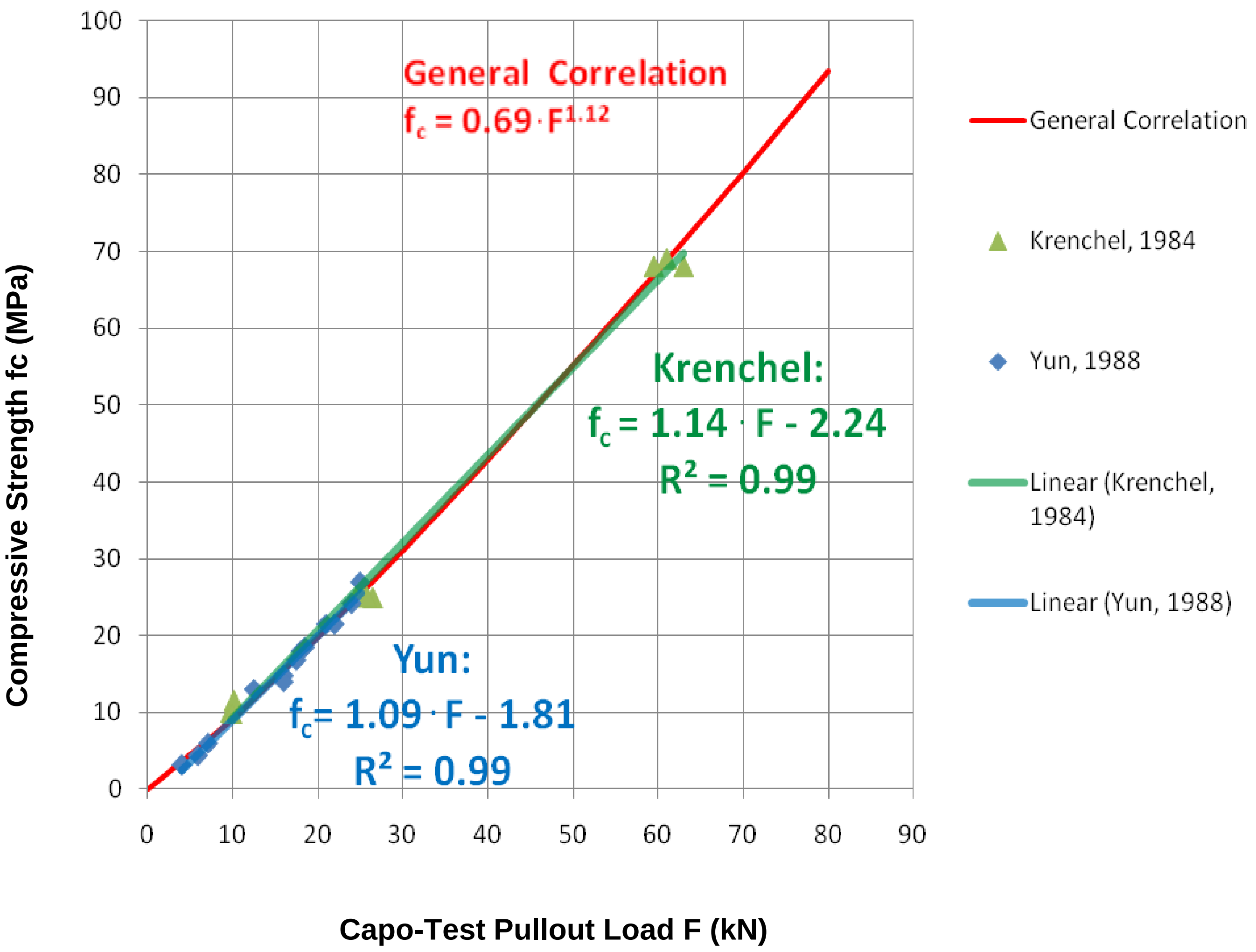


Fig.20)

Yun et all, 1988, ref (6)
Mortar
Average of 2 CAPO-TEST and 4 cores (150 mm x 300 mm) on slabs 1000 mm x 1000 mm x 300 mm
Slabs cured with wet burlap, fully hardened.

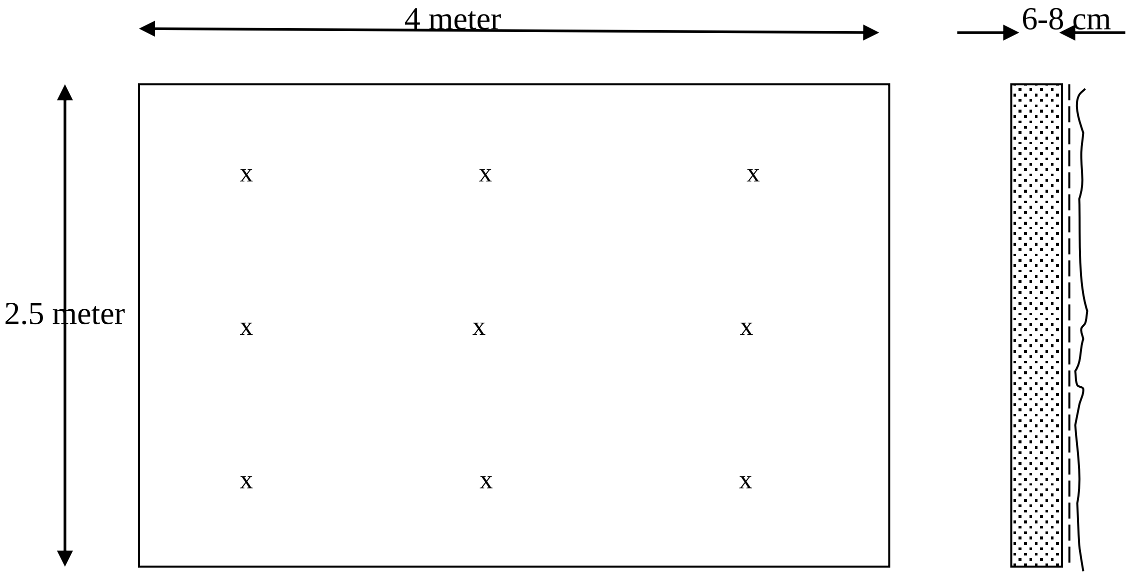
Fig. 21)


General Correlation
$f_c = 0.69 \cdot F^{1.12}$
Krenchel:
$f_c = 1.14 \cdot F - 2.24$
$R^2 = 0.99$
Yun:
$f_c = 1.09 \cdot F - 1.81$
$R^2 = 0.99$
Compressive Strength fc (MPa)
Capo-Test Pullout Load F (kN)
0
10
20
30
40
50
60
70
80
90
100
General Correlation
Krenchel, 1984
Yun, 1988
Linear (Krenchel, 1984)
Linear (Yun, 1988)

On-Site Testing Example:

CAPO-TEST performed on fully hardened shotcrete walls, 2.5 meter x 4 meter, 60 mm to 80 mm thick, ref (4)
In every wall 9 CAPO-TEST ´s were performed. The required cylinder strength was 30 MPa

In the middle of the shotcrete layer was positioned a welded wire mesh, spacing 5 x 5 cm, 6 mm thickness of the mesh



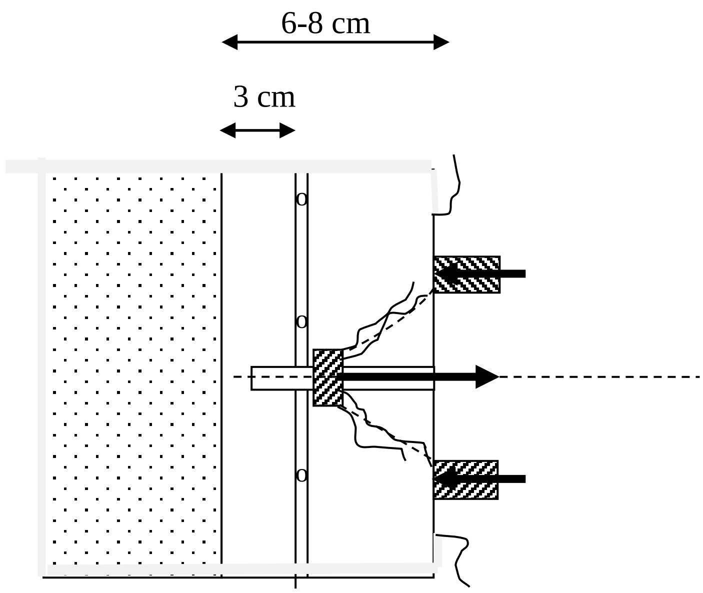


Fig. 22)

Summary of test results

Site No Wall #	**CAPO-TEST**				Related Cylimder Strength [x]) f_c, Average
	nos	**CAPO Strength F Average (kN)**	**S (kN)**	**V (%)**	(MPa)
16 Wall 1	**9**	**29.3**	**2.7**	**9.2**	30.3
64 Wall 3	**9**	**24.1**	**1.9**	**7.9**	25.4
86 Wall 2	**9**	**36.8**	**3.1**	**8.4**	39.1

[x]) Related 150 mm x 300 mm cylinder strength f_c in MPa calculated from Capo-Strength F in kN, using the general correlation $f_c = 0.69 \cdot F^{1.12}$

Note:
Cores for comparison were not made due to the limited thickness and position of the welded wire mesh in the middle of the shotcrete layer obstructing the compression tests of the cores.

Shotcreting in boxes for comparison was not performed.

Conclusion:

Only panel 16 and 86 met the required 28 days cylinder strength of 30 MPa, and they were accepted.

Panel 64 did not meet the requirement and was rejected. The reason for the lower strength was adding to much water in the nozzle during shotcreting.

The panel exhibiting the higher cylinder strength 39.1 MPa was produced using minimum amount of water added in the nozzle of the dry mix.

References:

(1) ASTM C900-15: “Standard Test Method for Pullout Strength of Hardened Concrete”, ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conchohocken, PA 19428-2959, USA
(2) EN 12594-3: “Testing of Concrete in Structures, Part 3: Determination of Pull-Out Force”, European Committee for Standardization, rue de Stassart 36, B-1050 Brussels, Belgium
(3) Herbert Krenchel & Claus Germann Petersen: “In-Situ Pullout Testing with LOK-TEST, Ten Years Experience”, Research Session of the CANMET/ACI International Conference on In Situ / Nondestructive Testing of Concrete, Ottowa, ON, Canada, Oct. 1984
(4) Claus Germann Petersen: “LOK-TEST and CAPO-TEST Pullout Testing, Twenty Year´s Experience”, NDT in Civil Engineering Conference, Liverpool, UK, Apr- 1997.
(5) Yun, C.H., Choi, K.R., Kim, S.Y. and Song, Y.C.: “Comparative Evaluation of Nondestructive Test Methods for In-Place Strength Determination”, Special Publication SP 112, American Concrete Institute, 1988

(6) Claus Germann Petersen & Ervin Poulsen ”Pull-Out Testing by LOK-TEST and CAPO-TEST with particular reference to the Great Belt Link, Danish Concrete Institute, Copenhagen, Denmark,1993
(7) Andrzej T. Moczko, Nicholas J. Carino & Claus Germann Petersen: “CAPO-TEST to Estimate Concrete Strength in Bridges”, ACI Materials Journal, Technical Paper, Title No 113-M76, Nov/Dec 2016.