

LOK-TEST & CAPO-TEST for in-situ strength

Section 2

Rationale and testing cases

Standards

Claus Germann Petersen

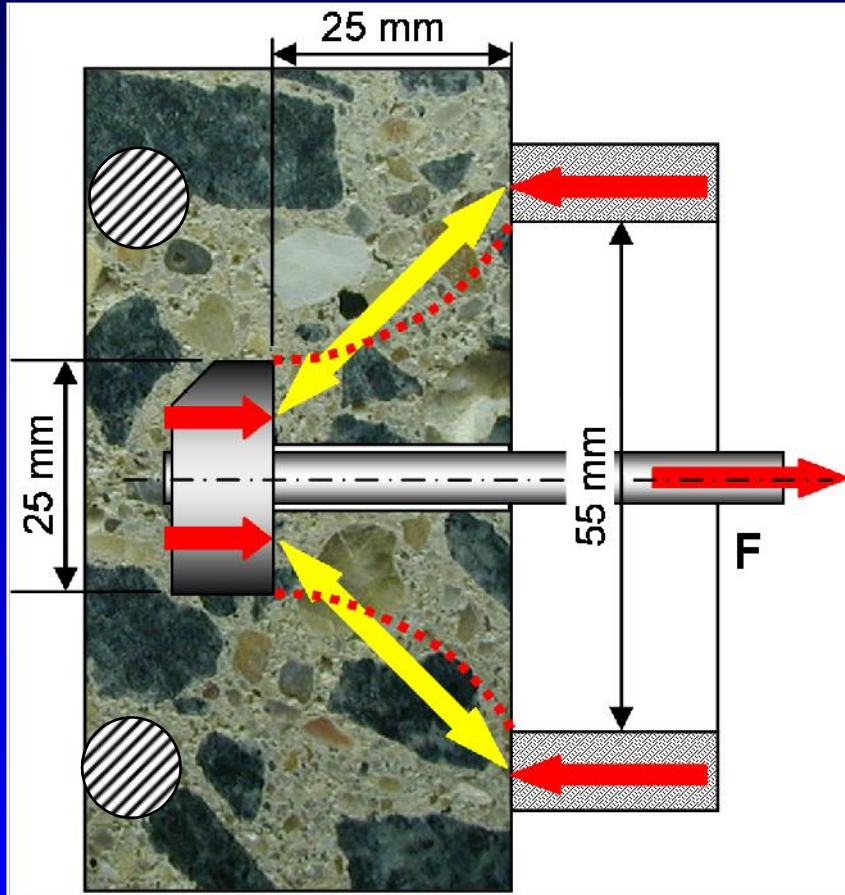
GERMANN INSTRUMENTS A/S

April 15th, 2019

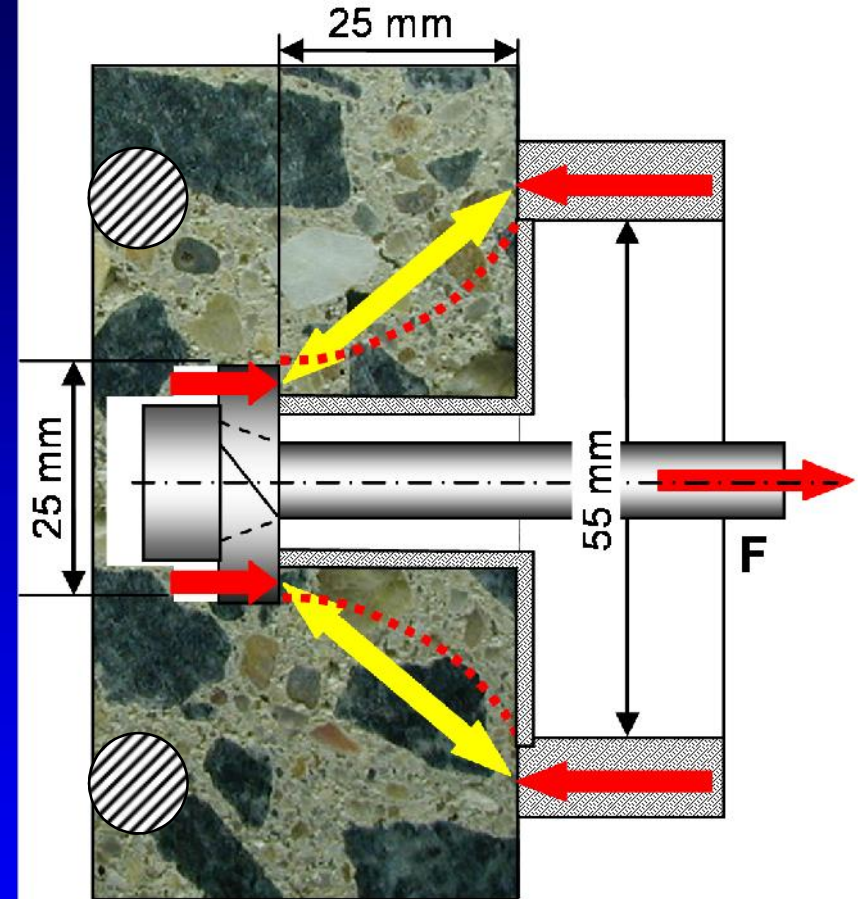
In-Situ Strength, why?

- Control of effects of transportation, compaction and curing, testing the finished structure
- Quality of the cover layer protecting the reinforcement against chloride ingress
- Eliminate shortcomings of cylinders and cubes
- Low strength of laboratory specimens
- Changed mixes, intentionally / not intentional
- Strength of existing structures for load carrying capacity
- Timing of safe and early loading operations

The two in-place test systems presented



LOK-TEST



CAPO-TEST

Rationale for in-place testing

1. In-situ strength assessment, general
2. Timing of safe and early loading
3. Testing of the finished structure
4. Mistreatment of the cover layer, curing
5. Further loading of columns
6. Tunnel elements quarantened
7. Old bridges before further loading
8. Shotcrete and bridge joints

Rationale for in-place testing

1st example

In-Situ Strength Assessment



Professor John Bungey
Emeritus Professor of Civil Engineering
University of Liverpool, UK



Professor Adrian Long, Emeritus Professor
School of Natural and Built Environment
Queen's University of Belfast

Early Age Acceptance of Concrete.

**A RADICAL RE-DESIGN OF THE
IN-SITU CONCRETE FRAME PROCESS**

DoE Project Ref.: BRE/SDD/ECBP.

Task 6:

**Early Age Acceptance of Concrete
(Improved Quality Management).**

Final Report

26/3/99

Prof. J.H. Bungey*, Prof. A.E. Long,**

**IN-SITU STRENGTH ASSESSMENT OF CONCRETE
- THE EUROPEAN CONCRETE FRAME BUILDING PROJECT -**

DR. M.N. SOUTSOS, PROF. J.H. BUNGEY*,
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Cardington Project, UK



LOK-TEST ready
for testing through
porthole in column
shutter

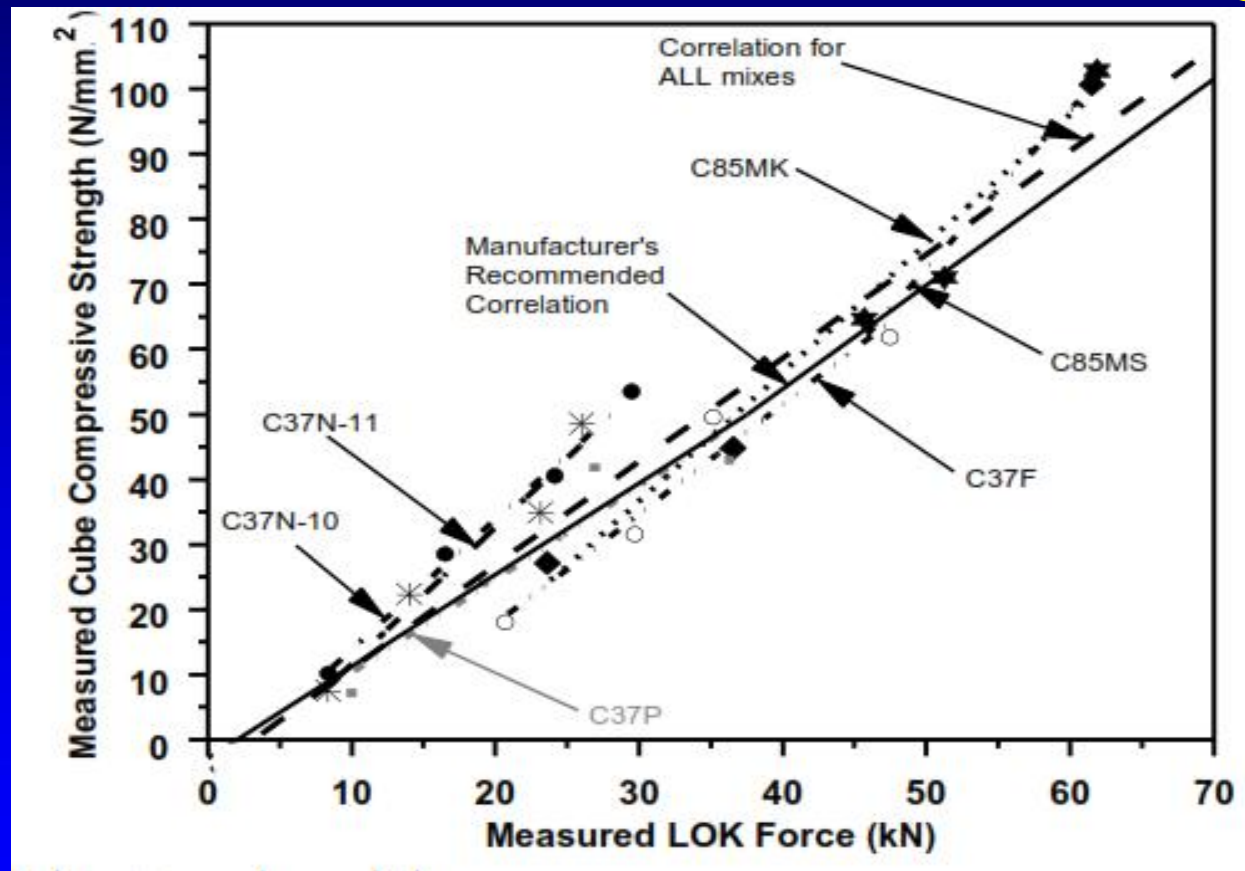
Extracts of the reports

- "The overall objective of the Cardington Project was to re-engineer the business process of such buildings in order to reduce costs, increase speed and improve quality"
- "In most countries in the world the quality of the concrete is assessed indirectly by measuring the strength of cubes or cylinders. ...it has its limitations in that problems are not detected until it may be too late In addition, these procedures can be subjected to abuse, either by making cubes prior to the addition of water to the mix, or in extreme cases, by the contractor supplying cubes from a specially prepared mix which will meet the specifications"
- All these shortcomings can be eliminated by measuring the strength properties of the concrete in-situ and at an early age. This also permits the effectiveness of compaction and curing processes to be incorporated in providing a reliable indication of the condition of the finished product"

Extracts, continued

- "The Danish LOK-TEST system was selected for this project since this is the version which has gained greatest commercial acceptance worldwide"
- "A companion CAPO-TEST system is also available in which tests may be conducted on hardened concrete without preplanning... This was also used in the project to provide supplementary information and to permit a controlled comparison of the two techniques under "field" conditions"
- "One key feature of these pull-out methods is the good sensitivity to compression strength and the relative insensitivity of correlations to mix variables such as aggregate type"
- "The combined correlation for all mixes used (7 different mixes) are surprisingly very close to the Manufacturers correlation" (next slide)

Correlations obtained for 7 different mixes, Cardington



7 Correlations obtained between temperature matched cubes and LOK-TEST in the Cardington Project

Test smart – Build right

Recommendation:

Best Practice Guide for In-Situ Concrete Frame Buildings, issued after the Cardington Project

BEST PRACTICE GUIDES FOR IN-SITU CONCRETE FRAME BUILDINGS...

...FROM THE EUROPEAN CONCRETE BUILDING PROJECT



Introduction
The European Concrete Building Project is a joint initiative aimed at improving the performance of the concrete frame industry.

The principal partners in the world's most ambitious concrete research program are:

**British Cement Association
Building Research Establishment Ltd
Construct - the Concrete Structures Group
Reinforced Concrete Council
Department of the Environment,
Transport and the Regions**

The program involves the construction of a series of full-sized concrete structures in the Large Building Test Facility at Cardington, where they are being subjected to comprehensive testing of the building process and of their performance.

With support from the DETR and the Engineering and Physical Sciences Research Council, the first of these buildings, a seven-story in-situ flat slab concrete frame, was completed in 1998. The results of investigations into all aspects of the concrete frame construction process are summarized in this series of Best Practice Guides.

These Guides are aimed at all those involved in the process of procurement, design and construction of in-situ concrete frames. They should stimulate fundamental change in this process in order to yield significant improvements in the cost, delivery time and the quality of these structures.

Early age strength assessment of concrete on site



Figure 1: The Lok-test jack in position.

This Guide provides recommendations for determining the strength of concrete on site at early ages (less than three days)

Key messages
Knowledge of concrete strength at an early age:

- Allows significantly increased efficiency of in-situ concrete frame construction.
- Enables early striking of formwork and its economic re-use. This is further explained in a companion Best Practice Guide, Early striking for efficient flat slab construction.
- Enables early prestressing with safety.
- Can give an indication of long-term strength, enabling early confirmation of the quality of the concrete as placed.

Best practice

- Use pull-out inserts cast into the concrete to determine early age strength.
- Horizontally cast members (e.g. slabs) - locate inserts, using a floating cup, on the top surface of the slab near the end of the pour.
- Vertically cast members (e.g. walls, columns) - locate inserts on the formwork, with provision for early access before striking.

BCA **BRE** **CONSTRUCT** **REINFORCED CONCRETE** **DETR**

British Cement Association concrete structures group

Rationale for in-place testing

2nd example

Timing of safe and early loading

John A. Bickley, D.Sc (Honoris Causa), P.Eng., FICE, FCSCE

Summary of Canadian experience using LOK-TEST for safe and early loading operations



A Brief History of Pullout Testing; With Particular Reference to Canada

A Personal Journey

By John A Bickley, P.Eng.

Introduction

From the thirties to the seventies a number of researchers worked on the development of the pullout test as an in-situ method of determining the strength of concrete in a structure. Research in Russia in the years 1934-1938 by Volf, Charckov and Gershberg was reported in 1938 by Skramtajeve. In the sixties and seventies Richards in the US and Malhotra in Canada carried out experiments with prototype equipment and initiated the drafting of an ASTM test procedure. During this period Kierkegaard-Hansen in Denmark established the relative dimensions of the pullout and pullout test equipment that resulted in a straight line correlation between pullout force and compressive strength.

A field research programme funded by the National Research Council of Canada showed that the pullout test was an accurate way of determining the compressive strength of concrete in-situ. However the 3 inch diameter pullout used by Richards and Malhotra resulted in large, cumbersome test equipment impractical for site use. In Denmark, using the relationships determined by Kierkegaard-Hansen, Canadian researchers designed a portable pullout tester that

Test Smart - Build Right

Extracts of the paper

Enter LOK-TEST. It may offend those purists who consider it Verboten to use a product name in a technical paper, but the rationale is that this name is to pullout testing as Kleenex is to a tissue and Xerox is to copying.

The equipment is well designed and made, and it is simple to use. A set of 10 LOK-TEST's can be tested and the strength of a 100 m³ slab cleared for form removal in 20 minutes.

It has been suggested that the need to place the inserts before the concrete is casted is somehow a defect in the system that compromise the validity of the test results. In practice it would be next to impossible to affect the test results. The practicalities of placing concrete do not and cannot include some directions to achieve an unnatural result. The inserts placed in different locations in a 100 m³ placement really are representative of that concrete. What is important is that a significant number of test results can be obtained quickly and economically, and allow the minimum strength of a placement to be calculated with a high degree of confidence (Bickley, 1982), This is the biggest advantage and the most significant difference between LOK-TEST and other test methods

Collapses referenced in John Bickley's paper



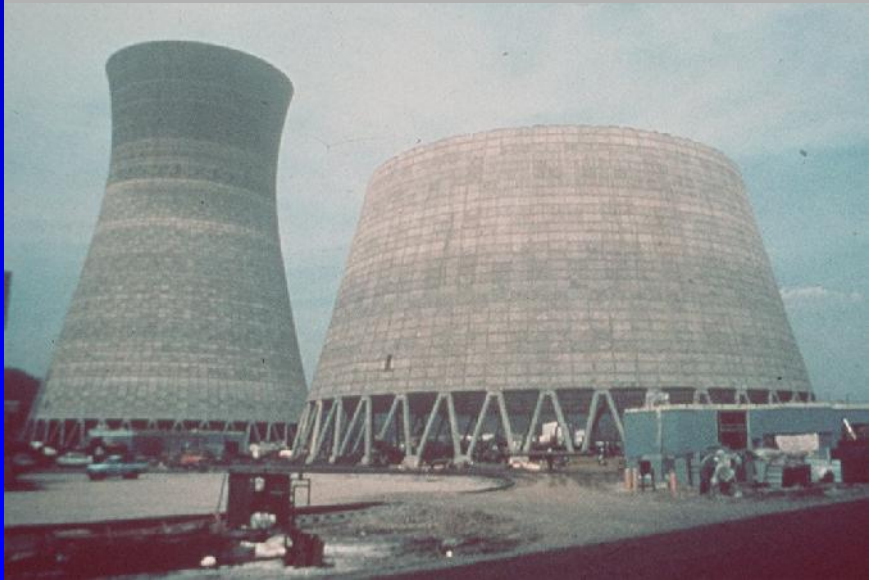
- Multi-story building collapse in Boston, USA.
- Field cured cylinders tested had passed the requirement.
- Subsequent investigation showed the in-place strength to be 50% of the cylinder strength at the time of formwork removal.

Willow Island, W.Va., USA

Cooling Tower Collapse, April 1978

- Failure due to insufficient strength to support next lift
 - 51 deaths

LOK-TEST was subsequently used to estimate in-place strength before moving to next lift,
24 inserts tested in each lift



Courtesy of NIST

Strength for Formwork Removal



Principal Mr. Sal Fasullo, C.E.T.,
Davroc & Associates Ltd., Canada

Mr. Sal Fasullo has during the years been in charge of and responsible for testing of +200,000 LOK-TEST' s

===== *Test smart – Build right* =====

Principal Mr. Sal Fasullo, C.E.T.

- Over the years Sal has provided his expertise on many high profile and technically challenging projects such as the CN Tower, Royal Bank Plaza, Scotia Plaza, BCE Place, the Bay Adelaide Centre, Simcoe Place, the Humber River Bridge Project and many more projects across North America where High Performance Concrete was utilized
- In addition, Sal has participated in the introduction of new advanced concrete testing systems such as Lok-Test, Maturity Testing, Pulse Velocity Testing, Rapid Chloride Permeability Testing, Impact-Echo Testing, Chloride Ionic Diffusion Testing and many others.
- Mr. Fasullo is a member in good standing of the Ontario Association of Certified Engineering Technicians and Technologists (OACETT), American Concrete Institute (ACI) and the Ready Mix Concrete Association of Ontario (RMCAO)

Statements by Mr. Sal Fasullo:

- "The Lok-Test System in my mind is the best for accuracy, speed of testing and reliability. You can place inserts at any locations you want to know the strength at"
- "We primarily always installed the Lok-inserts at the bottom of the slab because of the ease in the installation, we don't need to be on-site to install top surface floating Lok-inserts"
- "Concerning the higher strength at the bottom of the slabs, for our severe winters, the Contractors typically cover the top surface with insulating blankets, thereby reducing the differences between bottom and top surface strength"
- "In severe weather the top is protected with insulation blankets, but sometimes there is no protection, only forced air gas heaters on the underside of the slab. Temperatures on the underside of slabs are so hot you can hardly breath, or touch the aluminum forms, because they are too hot"

Why we use LOK-TEST?

- "1. The test system is a physical test, and not some predicted value from a maturity conversion table, or rebound conversion hammer table"
- "2. Normally we would install 15 Lok-Test inserts for a 100m³ slab pour, and test 10 inserts to obtain strength level of the concrete. This means that we are testing almost every load of concrete placed."
- "3. The Lok-Test system measures the actual strength of the concrete in-place, as compared to CIPOC or cast in-place cylinders which have been cast from concrete placed in the slab, ie., differences in casting and curing cylinders will normally yield lower compressive strength results, therefore delaying the time to remove forms."

- "4. The Lok-Test System will yield test results on ten (10) trucks of concrete, thus representing a cross-section of the concrete placed as compared to CIPOC or cast in-place cylinders, which have been cast out of two (2) truckloads of concrete, and a very small portion of the floor slab concrete."
- "5. Results of the Lok-Tests are made available at the time of testing, whereas the cylinders or cores have to be returned to our laboratory for end preparation capping, and testing which is at least two (2) hours after receipt of the specimens, plus about one (1) hour travel time back to the Lab."
- "6. Compressive strength results from the Lok-Test System will yield statistically valid test data, whereas other systems do not."
- "7. Considering the safety implications connected with form removal, I believe the Lok-Test system is clearly the best and preferred test method."

- "8. Cost comparisons with the different test systems are listed as follows:
- -Cast in-place field cylinders (4 tests) ~2.2 times more than ten (10) Lok-Tests.
- -CIPOC field cylinders (4 tests) ~3.5 times more than ten (10) Lok-Tests.
- -Cores (4 tests) ~6 times more than ten (10) Lok-Tests."

Examples of project using fast, accelerated constructions schedules

	20 Storey Building	15 Storey Headquarte	30 Storey Building	Twin Towers	14Storey Building ⁵	3Storey Centre	9Storey Condom.
Savings	(All Numbers are \$/1000)						
Interest	600	1750	188	NC	NC	533	43
Earlier Rental	200	NC	25	NC	NC	466	40
Formwork	120	25 ⁴	NC	75	NC	NC	NC
Reshoring	NC	NC	NC	NC	NC	NC	NC
Winter Heating	NC	NC	114	(0.3/pour/day)	NC	NC	NC
f ^l _c at 91 days	NA	50	38	62	23	NA	NA
Design	120	NA	NA	NA	NA	NA	NA
Overhead	NC	NC	20	NC	NC	NC	NC
Sub-Total	1040	1825	385	137	NC	999	83
Costs							
Concrete	20 ¹	320	152	56	93	20	0
Testing	15 ²	38	24	10	14	10	4
Sub-total	35	358	176	66	107	30	4
Net Saving	1005 ³	1467	209	71	NC	969	79

Accelerated construction, Savings to Owners, examples

Rationale for in-place testing

3rd example

Testing of the finished structure

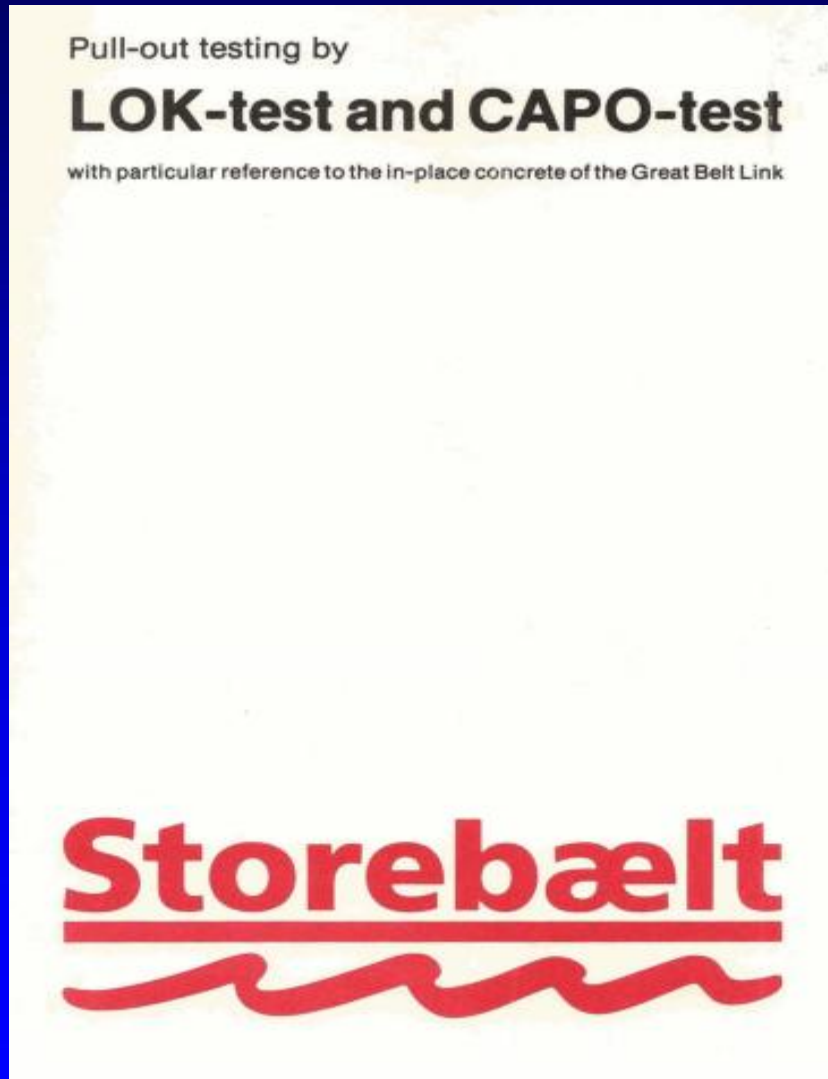
Great Belt Link, Denmark



Consisting of the high span bridge, the low span bridge and the tunnel

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Instruction Booklet and testing experience, Great Belt Link



LOK and CAPO Tests

The experience of pull-out test during
The Great Belt Link (Storebælt) project in Denmark

Extractions of the Storebælt Technical Publication:

Concrete Technology

Published by A/S Storebæltsforbindelsen

Copenhagen, Denmark, 1999

Extracts

- The Great Belt Link's Special Specifications for Concrete Works requires testing of the in-place concrete compressive strength.
- For this purpose the Special Specifications specified the application of pull-out testing by LOK-TEST and CAPO-TEST according to the Danish Standard DS 432.31
- The contractor's technicians who have been selected for the testing and the inspectors supervising the testing attended a course where the theoretical background was given as well as the practical skills in how to perform the testing. Diplomas were issued to those participants who passed the final examination with a satisfactory result

Extracts, cont' ed

- The relationship between pull-out force F and standard cylinder strength f_c is:

$$F = 0.95 f_c + 1.00 \text{ for } 2 \text{ kN} < F < 25 \text{ kN}$$

$$F = 0.80 f_c + 5.00 \text{ for } 25 \text{ kN} < F < 60 \text{ kN}$$

- DS 411 states the strength requirement to be fulfilled if at least 80% of the required potential strength of the concrete as measured on laboratory cylinders, well compacted and cured in water. The Great Belt Links Special Specifications for the Concrete Works follow this requirement

Correlations used

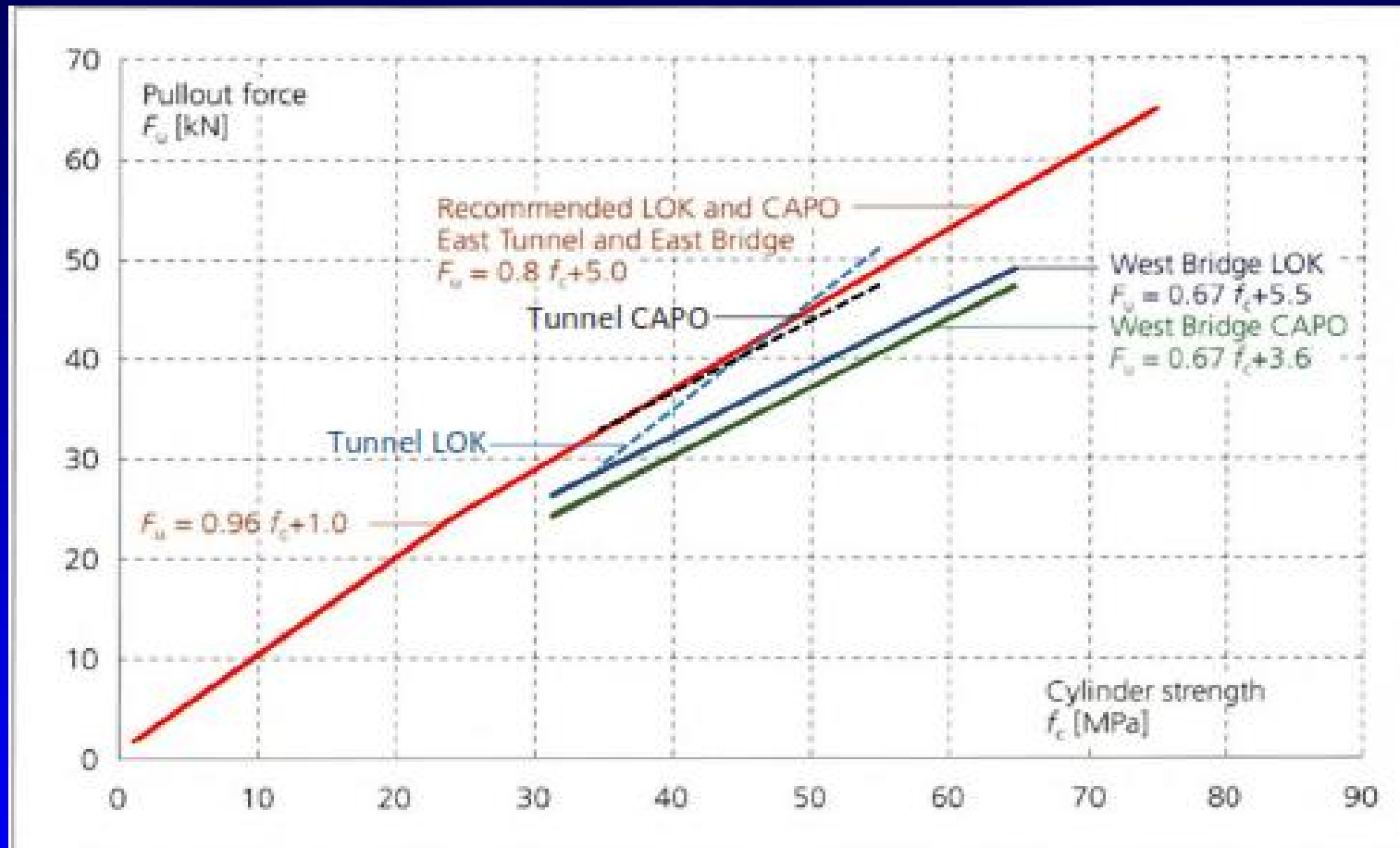


Fig. 10. Recommended correlation (red) between LOK-test and CAPO-test pull-out forces and 150 mm diameter x 300 mm long standard test cylinder compressive strength. This correlation was used for the East Tunnel and East Bridge whereas separate correlation relationships (blue and green) were established for the West Bridge.

Great Belt Link, Denmark



Pre-testing performed to establish the acceptable limits for LOK/CAPO-Test in relation to chloride permeability of the cover layer



Certification of the LOK/CAPO-Test technicians with Diploma

LOK-TEST / CAPO-TEST for QC



COMA-Meter for maturity. The LOK-TEST or CAPO-TEST values, corrected for maturity, had to be minimum 80% of the strength of lab cylinders, cured in water

CAPO-TEST on the Great Belt Link, Denmark for QC of the cover layer. 45,000 tests were conducted on the tunnel, the low span bridge and the suspension bridge

Testing examples at the Great Belt Link, Denmark



CAPO-TEST of the abutments and
of the tunnel elements

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Extracts of results

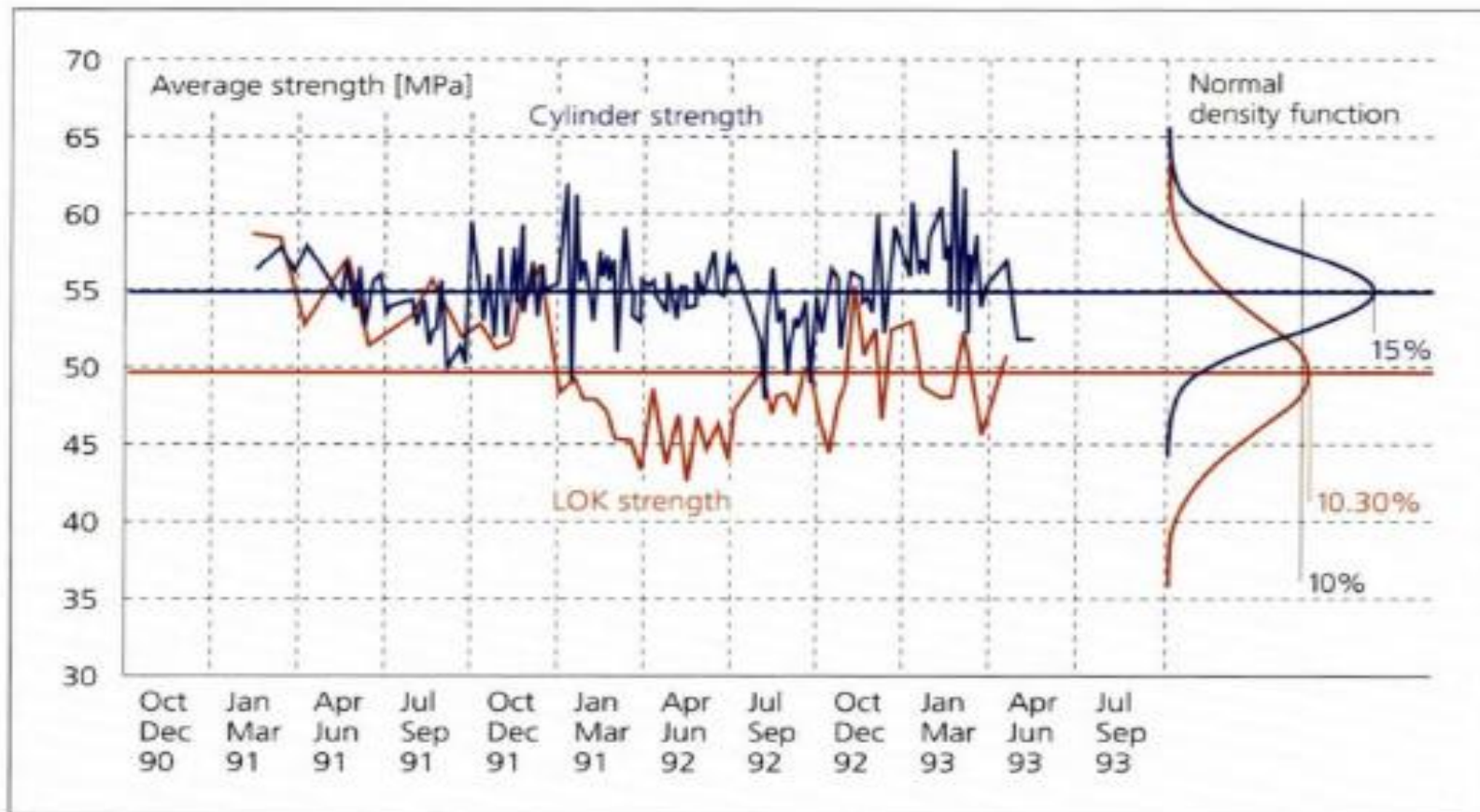


Fig. 11. West Bridge, rail girder inspection sections mix type B. Average strength results per inspection section of LOK-test and cylinder strength after 28 days. The average LOK-test strength for the entire production was 90% of the average cylinder strength. The coefficients of variation for the average LOK-test strength and average cylinder strength were 0.079 and 0.049 respectively.

Rationale for in-place testing

4th example

Mistreatment of the cover layer

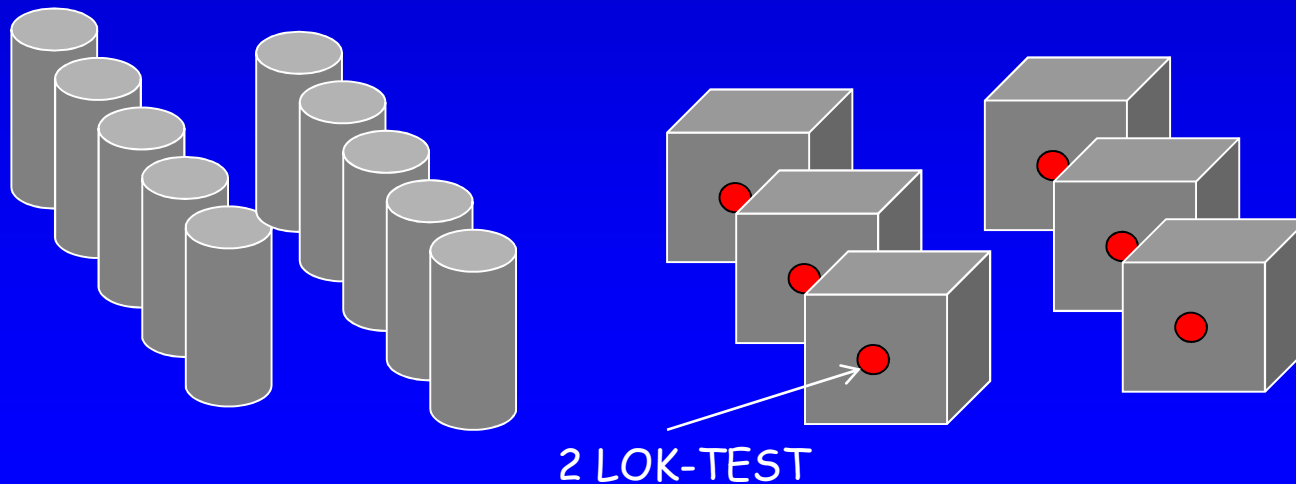
Curing

Mistreatment of the cover layer

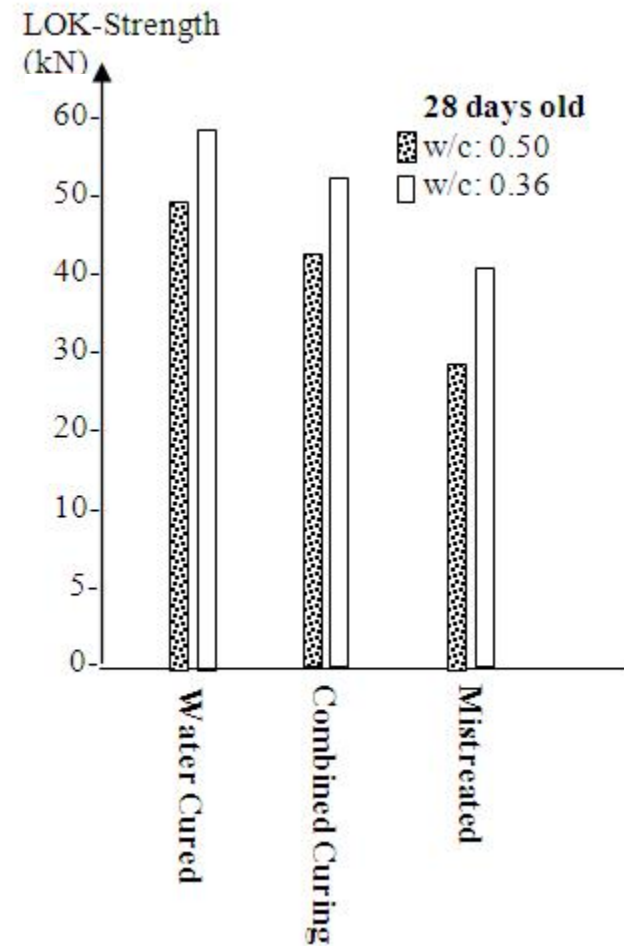
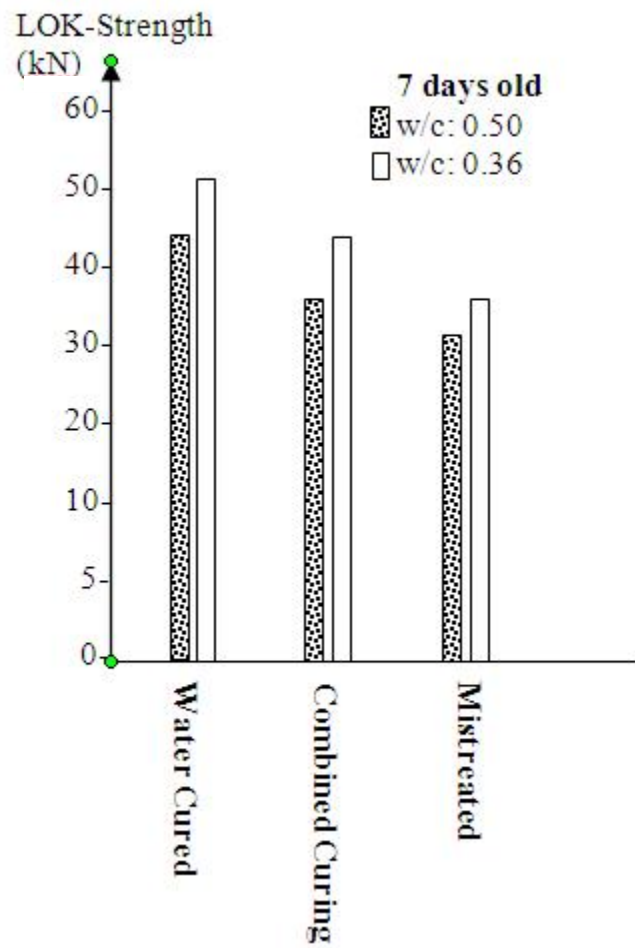
- Danish research of mistreatment of the cover layer (curing in windy conditions at 45 °C) has shown a reduction of the LOK-TEST strength of up to 40%
- Similarly, a 10% reduction has been found if the specimens are cured in air compared to water curing
- Such bad curing conditions will lead to increased chloride penetration of structures subjected to chlorides
- The results from Krenchel 69, DTU, are shown in the next 5 slides

Curing conditions

- 60 cylinders and 60 cubes, 200 mm, with 2 LOK-TEST inserts in each, divided in three groups, each 30 and 30 specimens
- Half with w/c ratio of 0.50, half with w/c ratio of 0.36
- One group cured in water (Water Cured)
- One group water cured 1 day, afterwards placed in air (Combined Curing)
- Last group water cured one day, afterwards placed in a heating chamber with air circulation at 45°C (Miscured)



LOK-TEST results



Reduction in LOK-Strength

- Combined cured specimens compared to water cured:
- *After 7 days:*
 - for w/c-ratio 0.50: 17% reduction
 - for w/c-ratio 0.36 : 14% reduction
- *After 28 days*
 - for w/c-ratio 0.50 : 8% reduction
 - for w/c-ratio 0.36 : 6% reduction

Reduction in LOK-Strength

- Miscured specimens compared to water cured:
- *After 7 days:*
 - for w/c-ratio 0.50 : 23% reduction
 - for w/c-ratio 0.36 : 30% reduction
- *After 28 days:*
 - for w/c-ratio 0.50 : 40% reduction
 - for w/c-ratio 0.36 : 31% reduction

Chloride ingress

- Badly cured cover layers have exhibited very low service lives based on chloride diffusion
- In several cases the lack of sufficient hydration of the cover layer have resulted in 4-6 years remaining service life against chloride diffusion compared to +70 years on parts on the same structure with a well hydrated cover layer, good cured.
- LOK-TEST / CAPO-TEST offer a quick solution to check the cover layer quality of the finished structure for QC purposes.

Deeper testing than at the surface 25 mm



Deeper embedment of the LOK-TEST insert can be made using e.g. the L-49 insert as illustrated adjacent.

Using this insert the testing surface will be lowered 20 mm making comparison possible to the 25 mm top layer

Rationale for in-place testing

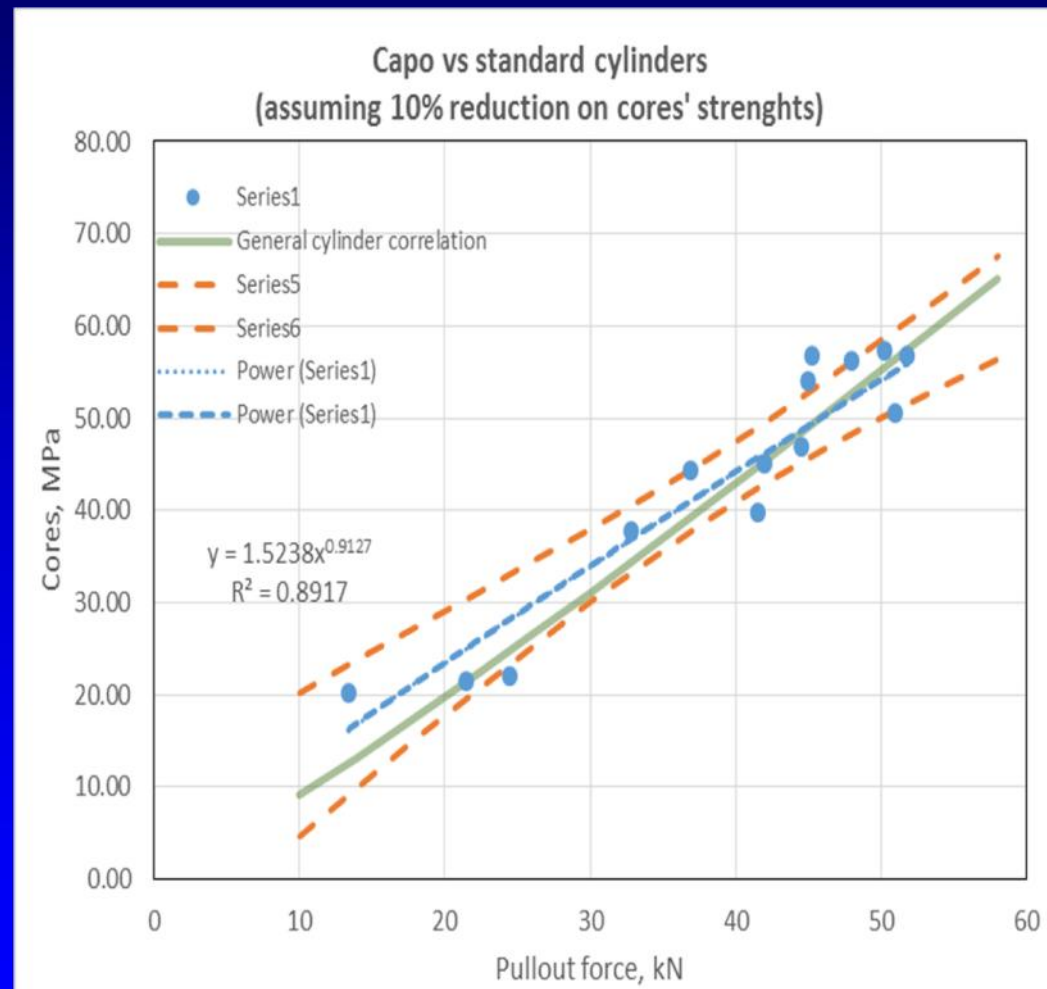
5th example

Further loading of columns

Further loading of columns of a high rise building



Correlation obtained to cores



Li, Desai & Bullock: "In-place estimation of concrete compressive strength using post-installed pullout", Journal of Testing and Evaluation, ISSN 0090-3773

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CAPO-Testing of the columns



Acceptable failures



Results: All columns tested had a strength of minimum of 55 MPa cylinder strength.

The required strength was 45 MPa, and the columns were accepted for further loading

Rationale for in-place testing

6th example

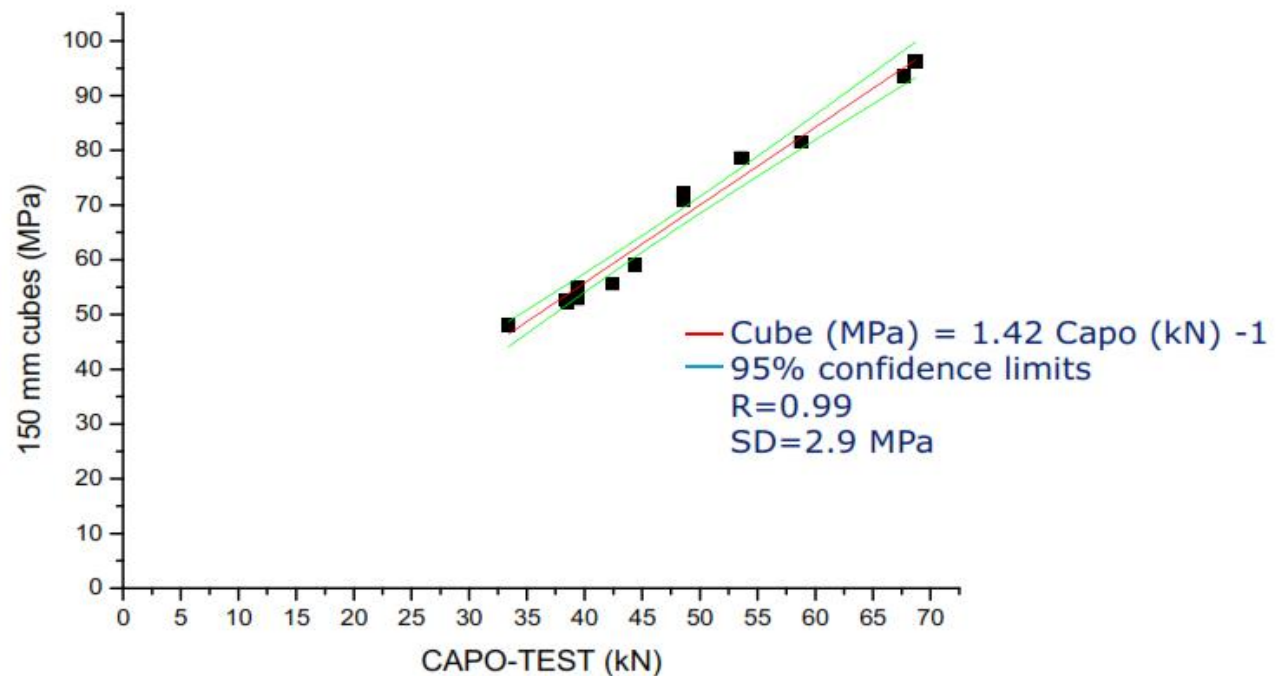
Quaranteneed tunnel elements

CAPO-TEST on the French-British Channel Tunnel Elements

- Production elements were cured in a heating tunnel together with standard cubes for acceptance
- The gypsum in the cement was changed unknowingly and over a period with constant production the cubes showed too low strength
- The tunnel elements produced in this period were quarantened and needed to be tested for acceptance of the strength at a later age
- CAPO-TEST was selected to perform the strength testing

Correlation to cube strength

Translink tunnel segments



The correlation obtained match the general cube relationship $f_c = 0.79F^{1.14}$

Ref. Worthers, "In-situ compressive strength testing of precast tunnel lining segments using CAPO-TEST", Translink Joint Venture, IST0041090-1, 1990

CAPO-TEST on elements



Testing with CAPO-TEST in progress, three tests were made in each element

All the quaranteened elements were accepted

Rationale for in-place testing

7th example

Old bridges before further
loading

Polish Bridges for further loading

- Due to further loading from military vehicles the Polish Bridges needed to be upgraded.
- Testing for compressive strength was made first in a study reported here, where cores, CAPO-TEST and rebound hammer were used for the estimation

Comparative study Polish bridges for increased loading

- Cores, sawcut, capped, tested after 5 days drying in lab conditions (100 mm diameter x 100 mm cores)
- CAPO-Test in-situ, double amount of cores
- Schmidt Hammer in-situ, up to 20 locations, each 6 tests
- Schmidt Hammer on side of cores prior to compression tests

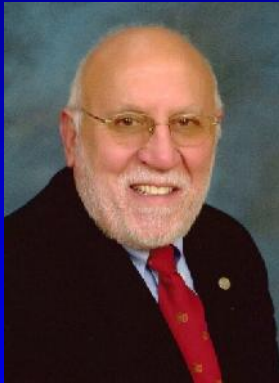
NOTE: All Schmidt Hammer results have been reduced by an "Aging Factor" of 1.4 recommended by manufacturer

Reported in ACI Materials Journal, Dec 2016⁵⁵

Profesor
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Dr. Nicholas
J. Carino



Mr. Claus
Germann
Petersen



ACI MATERIALS JOURNAL

TECHNICAL PAPER

Title No. 113-M76

CAPO-TEST to Estimate Concrete Strength in Bridges

by Andrzej T. Moczko, Nicholas J. Carino, and Claus Germann Petersen

This paper addresses whether carbonation in existing concrete structures affects the compressive strength estimated using the CAPO-TEST, a post-installed, pullout test conforming to ASTM C900 and EN 12504-3. Fifteen bridges, ranging from 25 to 52 years of age at the time of testing, were investigated. For each bridge, average values of core strengths and CAPO pullout strengths were obtained. Carbonation depth, which varied from 2 to 35 mm (0.08 to 1.4 in.), was measured using chemical staining methods. It was anticipated that, as the depth of carbonation increased, the pullout strength would increase for the same underlying concrete strength. Thus, the in-place compressive strength estimated on the basis of the manufacturer's general correlation would be expected to systematically exceed the strength measured by the cores. It was found that, on average, the compressive strength estimated from the CAPO-TEST and the general correlation was only 2.8% greater than the measured core strength. More importantly, there was no correlation between depth of carbonation and the relative error of the estimated strength based on the CAPO-TEST.

Keywords: CAPO-TEST; carbonation; core strength; correlation; existing structures; in-place strength; pullout test.

INTRODUCTION

The aging of concrete bridges in combination with increased service loads and high replacement costs increases

of the authors⁴ in a comparison of strengths estimated by rebound hammer compared with measured core strengths. Despite the use of a recommended "aging reduction factor" of 0.7 to account for carbonation, the estimated compressive strength from rebound values was found to be, on average, approximately 25% higher than the core strengths.⁴ Without applying this "aging reduction factor," the strength estimate would have been, on average, approximately 80% higher than the core strengths. There is no general correlation between rebound number and compressive strength. Therefore, each structure has to be evaluated based on a correlation developed with cores from that structure.

Another popular technique is measuring the speed of a pulse of ultrasonic stress waves, typically called the ultrasonic pulse velocity (UPV). For a given concrete strength, there are several factors that will affect the UPV of the concrete, such as aggregate type, aggregate content, and moisture content.³ In mature concrete, small differences in UPV can correspond to large differences in compressive strength, that is, UPV is relatively insensitive to changes in concrete strength. In addition, in reinforced concrete, the presence of reinforcement can lead to inaccurate values of UPV. While UPV is not known to be influenced by

Comparative Strength Estimates from 50 Polish Bridges, summary



Zglobice Bridge 32 years old



Wisna Bridge 35 years old

Average	Cores (MPa) V (%)		CAPO-TEST (MPa) V (%)		Schmidt / Structure (MPa) V (%)		Schmidt / Cores (MPa) V (%)	
Strength	32.8	9.5	33.5	11.7	55.9	16.4	44.5	15.1

Carbonation depth: 2 mm - 35 mm

Source: Moczko, A.: "Comparative Study of In-Situ Strength Measurements on 50 Polish Bridges", University of Wroclaw, Poland, 2007

CAPO-TEST, Polish bridge slab



CAPO-TEST on Polish bridges

COMA-Meter



Cores for correlation purpose



Bridge No.	Cores from structure		Capo-Test on structure		Schmidt Hammer on structure		Schmidt Hammer ⁶⁰ on cores	
	MPa	Av. of	MPa	r(CT)	MPa	r(L)	MPa	r(LM)
1	19.6	6	20.3	+3.4%	36.9	+88.3%	28.4	+44.9%
2	24.7	3	26.9	+8.9%	37.4	+51.4%	28.8	+16.6%
3	29.7	4	31.8	+7.1%	49.5	+66.7%	38.2	+28.6%
4	34.2	3	36.8	+7.6%	56.8	+66.1%	43.1	+26.0%
5	33.3	4	32.3	-3.0%	61.6	+85.0%	49.3	+48.0%
6	34.2	3	37.6	+9.9%	54.5	+59.4%	36.5	+6.7%
7	35.4	4	37.1	+4.8%	66.3	+87.3%	57.0	+61.0%
8	37.1	3	35.9	-3.2%	56.9	+53.4%	46.1	+24.3%
9	37.5	4	36.8	-1.9%	70.9	+89.1%	61.0	+62.7%
10	42.0	3	39.7	-5.5%	68.4	+62.9%	57.4	+36.7%
Avg.	32.8		33.5	+2.1	55.8	+70.0%	44.6	+36.0%

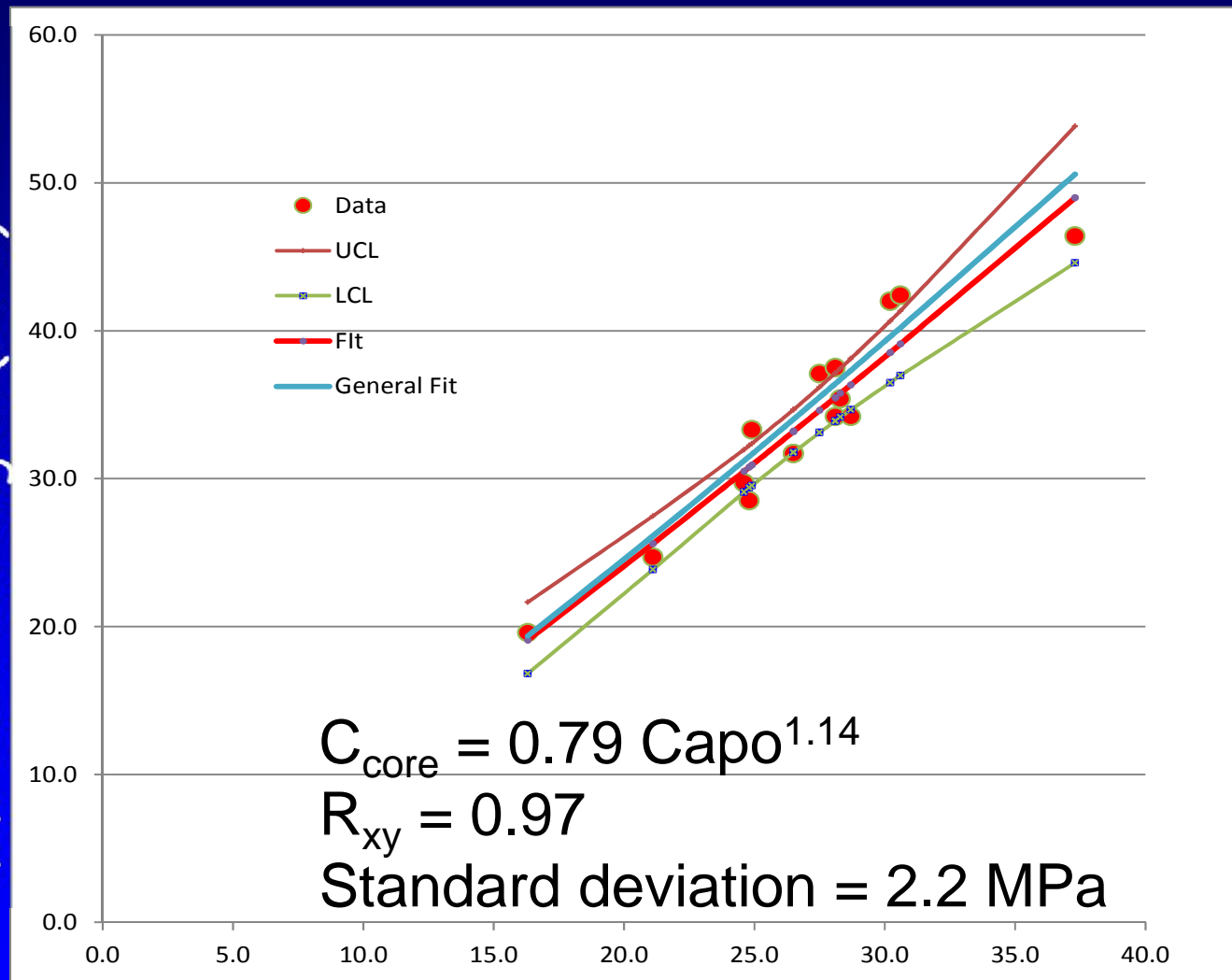
Comparative testing, Polish experience, bridges 20-30 years old, ref. A. Mozcko,, Wroclaw University
 Note: The Schmidt Hammer results have been reduced by 1.4, the "aging" factor recommended by the manufacturer

Test smart – Build right



Correlation from Polish bridges

100 mm dia x 100 mm core
strength (MPa) equiv. to 150
mm cube strength (MPa)



Capo-Test (kN)

Test smart – Build right



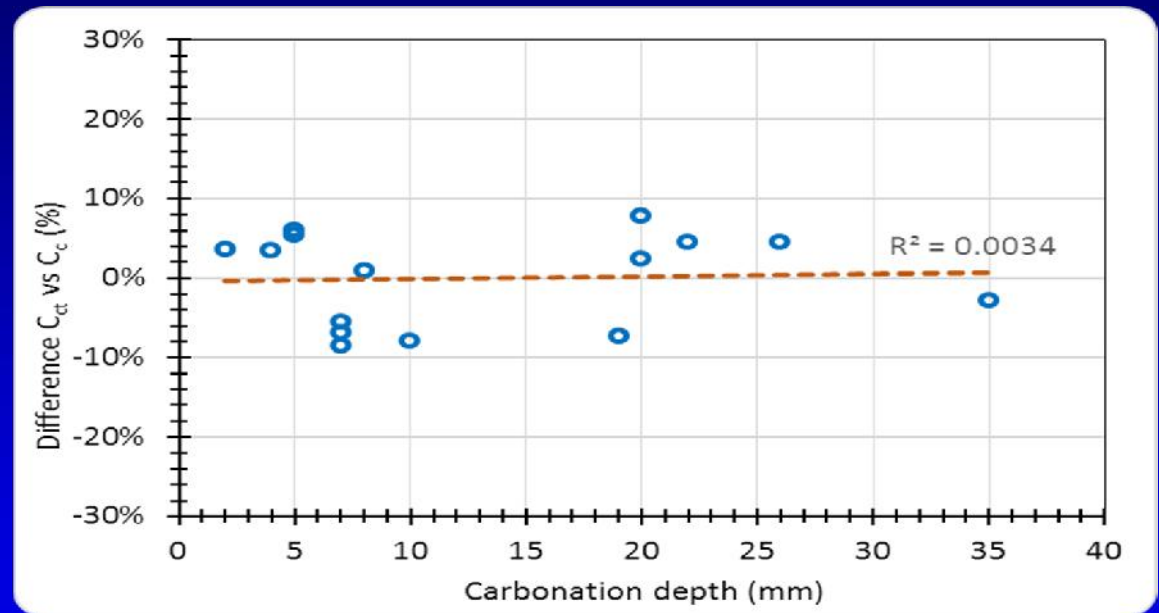
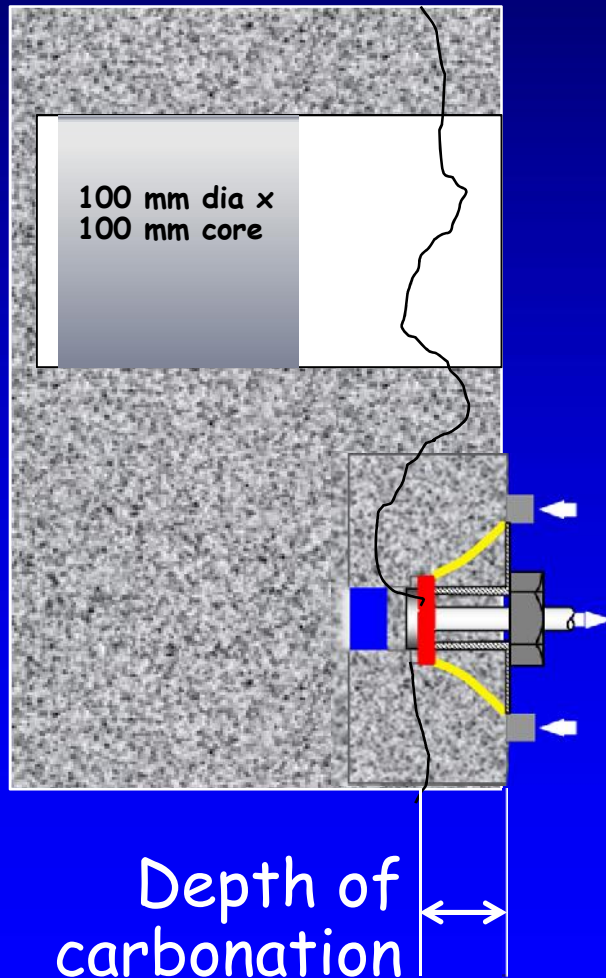
Comparison to the general correlation for cubes

Note that the correlation found $C_{\text{core}} = 0.79 \text{ Capo}^{1.14}$ match closely the general correlation for cubes $C_{\text{cube}} = 0.76 \text{ Capo}^{1.16}$

As a 100 mm dia. core, 100 mm long gives a strength equivalent to the strength value of a 150 mm cube, the following general relationship may be applied:

$$C_{\text{cube}} = 0.79 \text{ Capo}^{1.14}$$

No effect of carbonation



Conclusion: the effect of carbonation on the CAPO-TEST pullout strength is neglectable

Ref: Moczko, (2010)

Rationale for in-place testing

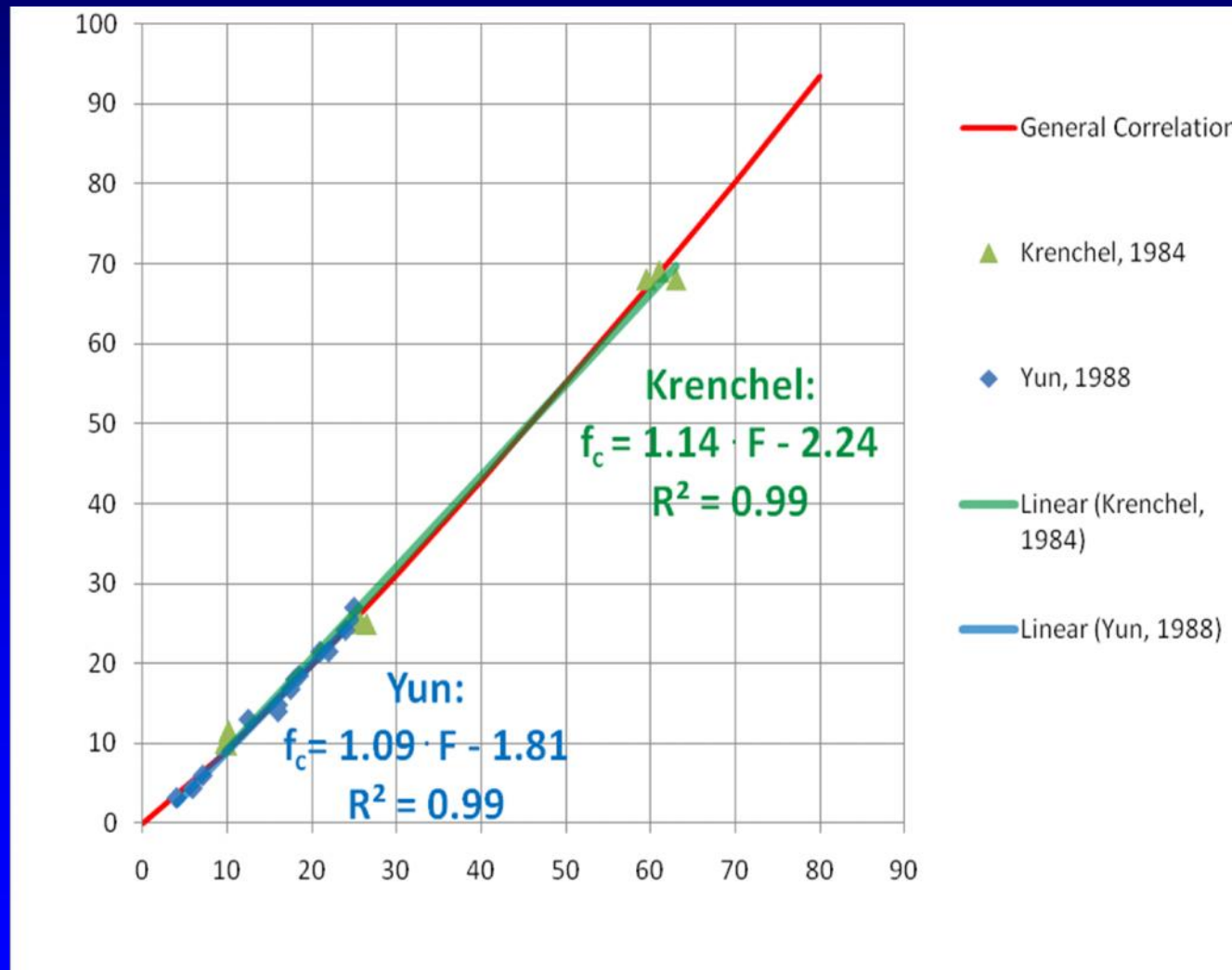
8th example

Shotcrete and bridge joints

Testing of shotcrete

- The "normal" testing is to test cores from shooting in boxes, prior to or during the job
- With the CAPO-TEST strength testing can be done directly on the structure, the finished shotcrete, quickly and reliable
- Testing may also be done on the structure at an early age, timed by maturity, e.g. By inserting COMA-Meters

General correlation used for shotcrete



Shotcrete



Requirement 30 MPa,
average strength
measured 32 MPa,
variation 5%



Parts of a shotcreted finished tunnel had collapsed, and the tunnel was flooded. The strength required 30 MPa had not been met due to adding too much water to the dry mix. After repairing the tunnel CAPO-TEST was used to test the shotcrete with less water added in the mix

Test smart – Build right

CAPO-TEST for QA on bridge joints



All CAPO-TEST results > 50 kN,
equiv, to 55 MPa cylinder strength, with minimal disruption compared to cores
and much faster (10-15 minutes) with results immediately available

Test smart – Build right

Summary and Considerations

Summary

- LOK-TEST and CAPO-TEST offer the possibility of testing the structure directly, quickly and reliably for compressive strength, minimizing the need of laboratory work and cumbersome testing of cores or specimens on-site
- The tests measure directly the compressive strength in-situ.
- A robust correlation is available documented in many investigations
- Engineering judgement should be exercised wheather the testing is for structural capacity evaluation or for cover layer quality

Summary

- LOK-TEST and CAPO-TEST are far superior to indirect test methods like rebound hammer, UPV and probe penetration tests as far as accuracy and reliability are concerned. These indirect test needs correlation to the concrete in the structure by cores, which is close to impossible to do as there will be no span in the correlation. Also they are much less sensitive and much less precise
- LOK/TEST and CAPO/TEST are simple to perform, especially LOK-TEST and the test results are immediately available on-site

LOK-TEST advantages

- Once the inserts are installed testing can be made at any time, e.g. timed by maturity
- Easy to perform and very reliable
- One test takes 3-5 minutes to perform
- Test results are immediately available
- Loading can be performed to a required strength or exactly to failure with no disruption
- If pulled out, cause only a small fracture cone hole easily to be patched
- Portable equipment

CAPO-Test advantages

- Does not require pre-planing test locations
- Can perform test at any accessible location
- Permits testing of existing structures
- 15-20 minutes per test
- Test results immediately available
- Cause only a small fracture cone hole compared to a 100 mm coring hole, easily to be patched
- Portable equipment (electricity and water is needed)

Summary

- General correlation according to European Norm **EN 12505-3: 2005** and **EN 13791:2007** as well as **Canadian Standard CSA-A23.2-15** and
- Following the **US standard ASTM C 900-06** confirm general correlation

EN 12505-3: 2005:

"The correlation between strength and pullout force for the apparatus being used should be established experimentally. It has been shown that for a given type of apparatus the relationship between pullout force and compressive strength is similar over a wide range of concretes and that a general correlation can be used with reasonable accuracy"

CSA-A23.2-15:

"For a given configuration of insert, bearing system, and depth of the insert, there is a correlation between pullout strength and standard cylinder's compressive strength", specifying the use of LOK-TEST

EN 13791:2007:

"Well-established relationships may be used"

ASTM C 900-06:

"For a given concrete and a given test apparatus, pullout strengths can be related to compressive strength test results.....Before use, these relationships must be established for each test system and each new concrete mixture"