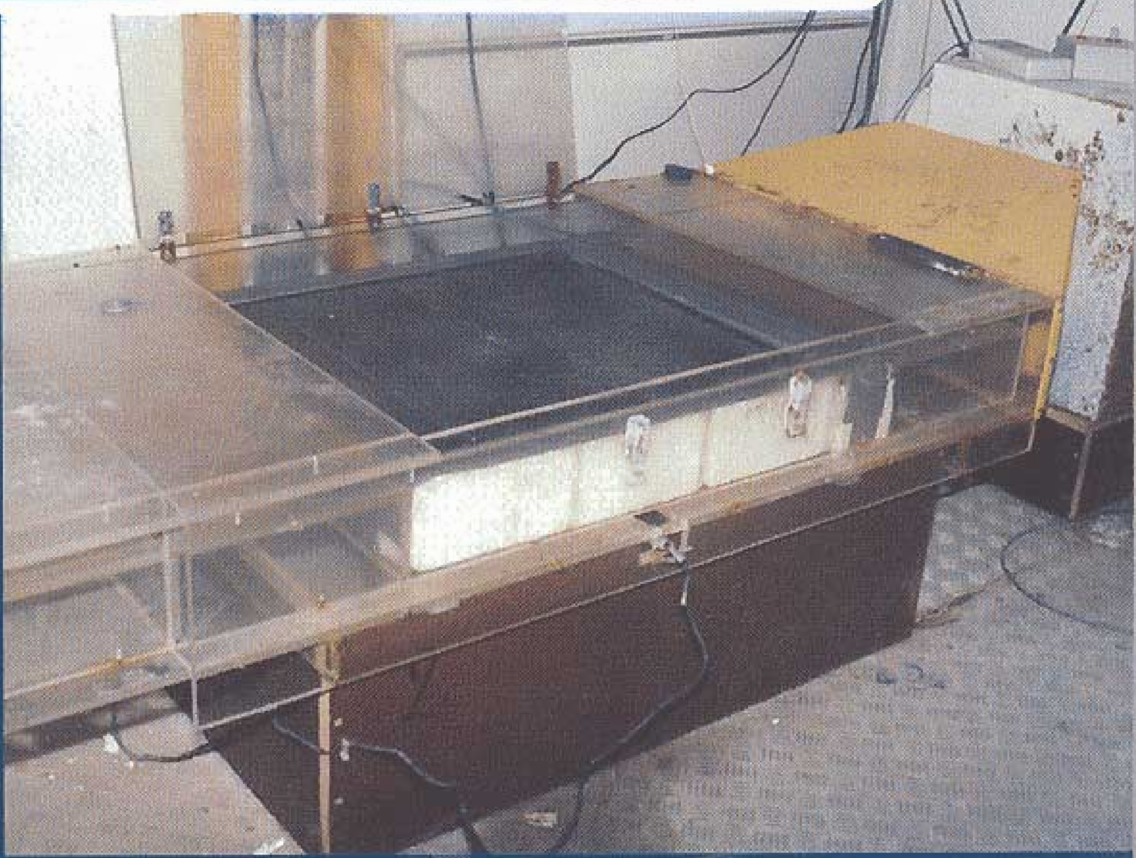
HETEK

Curing – Supplementary research – Proposal



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Abstract

This report forms a part of the Danish Road Directorate's research programme called High Performance Concrete - The Contractor's Technology (abbreviated to HETEK). HETEK is divided into eight parts where part no. 6 concerns Curing.

The supplementary research is divided into four phases where phase 1 is curing tests in laboratory, phase 2 is evaluation of obtained test results and establishment of theory. Phase 3 is verification in field and laboratory and phase 4 is evaluation and definition of conformity criteria.

In phase 1 fourteen different curing methods will be tested in DTI's laboratory, where it is possible to expose the concrete surface to a controlled temperature, relative humidity and wind velocity. At the same time the evaporated amount of water is weighed continously. The fourteen curing methods are based on the contractors experience and includes also the extreme methods such as water curing and no protection. All the tests will be performed on a typical concrete used for bridge constructions.

The quality of the concrete surface will be characterised based on testing of the parameters micro structure including a description of the cracks, Scanning Electro Microscopy, resistance to chloride penetration, cappillary absorption and resistance to carbonation.

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0. Preface

This project regarding curing is part of the Danish Road Directorate's research programme, High Performance Concrete - The Contractor's Technology, in Danish Højkvalitetsbeton - Entreprenørens Teknologi abbreviated to HETEK.

High Performance Concrete is concrete with a service life in excess of 100 years in an aggressive environment.

The research programme includes investigations regarding the conctractor's design of high performance concrete and execution of the concrete work with reference to obtain the requested service life of 100 years.

The research programme is divided into eight parts within the following subjects:

- chloride penetration
- frost resistance
- autogenous shrinkage
- control of early-age cracking
- compaction
- curing (evaporation protection)
- trial casting
- repair of defects.

The Danish Road Directorate has invited tenders for this research programme which primarily is financed by the Danish Ministry for Business and Industry - The Commission of Development Contracts.

This project regarding curing is performed by:

Danish Technological Institute represented by the Concrete Centre:

- Anette Berrig (Head of the project)
- Marlene Haugaard
- Chr. Munch-Petersen
- Kirsten Riis

and

Danish Concrete Institute represented by the three Contractors:

Højgaard & Schultz A/S - Per Fogh Jensen
Monberg & Thorsen A/S - Jan Graabek
Rasmussen & Schiøtz A/S - Per Jeppesen.

The purpose of the project is to investigate the effect of different curing methods on the quality of the concrete surface and to prepare a guideline regarding curing.

Curing method is defined as the combination of the type of surface protection and the protection period.

The results of the project will be published in the following reports:

HETEK - Curing - State of the Art
HETEK - Curing - Supplementary Research - Proposal
HETEK - Curing - Phase 1: Laboratory Tests
HETEK - Curing - Phase 2: Evaluation of Test Results
HETEK - Curing - Phase 3: Verification Tests
HETEK - Curing - Phase 4: Final Evaluation and Definition of Conformity Criterias
HETEK - Curing - Main Report
HETEK - Curing - Guideline.

March 1996

Per Fogh Jensen
Anette Berrig
Steering Committee of the HETEK-Curing project

1. Introduction

With reference to the state of the art report HETEK - Curing - State of the Art [Berrig, 1996], a proposal for supplementary research is described in this report. The supplementary research necessary for preparing an instruction concerning curing of concrete is described below. Curing of concrete is necessary to ensure a good quality of the concrete surface layer meaning a dense concrete without cracks. The good quality shall ensure a long durability of the concrete structure. Curing of concrete involves protection both of the fresh concrete and during the first time of the hardening period. The protection shall ensure the concrete against destructive evaporation.

In todays concrete specifications for construction projects requirements regarding curing are stated. The requirements normally states how early and how long the concrete surface shall be protected against evaporation. In the last years there has been a tendency to more and more strict requirements meaning earlier protection and longer protection period.

Some investigations performed by DTI and Dansk Beton Teknik A/S [Lundberg, 1994] have indicated that a shorter period with formwork on the concrete surface combined with a curing membrane result in a higher quality of the concrete surface measured as number of micro cracks compared with concrete protected with formwork for a long period.

It is therefore desirable to get more information about how effective the curing must be to obtain a good concrete quality.

The aim of the supplementary research is to rank different curing methods as a function of obtained concrete surface quality. These informations shall be used in a revision of the existing requirements concerning time of protection, protection period and type of protection.

The supplementary research will be divided into four phases as follows:

Phase 1: Curing tests in laboratory
Phase 2: Evaluation of obtained test results and establishment of theory
Phase 3: Verification tests in field and laboratory
Phase 4: Evaluation and definition of conformity criteria

2. Phase 1: Curing Tests in Laboratory

In phase 1 fourteen different curing methods will be tested in DTI's test set-up described in [Berrig, 1992]. The test set-up developed at DTI makes it possible to expose the concrete surface to a controlled temperature, relative humidity and wind velocity. At the same time the evaporated amount of water is weighed continuously.

2.1 Testing of Different Curing Methods

The fourteen different curing methods are based on the contractors experience. Often used curing methods are included. The test programme is shown in figure 2.1. The contractors experience is based on how practical and economic the curing methods are.

Extreme curing methods such as water curing and no protection are also tested to cover a wide spectre of curing methods. This will presumably be a help concerning the description of theory.

The chosen curing compound is based on water and ester with an efficiency of 84 % according to TI-B 33.

The chosen formtype is a 18 mm waterproff plywood form for the surface to be tested. The rest of the form is made of plexiglass. The plywood form side will be treated with a form oil which is based on water and ester.

All the chosen products are often used in common practise and recommended by all contractors involved in this project.

Curing methods where form liner is used will not be tested in the laboratory. It is not possible to get the right benefit of the liner caused by the small test specimens because the benefit depends on the form pressure.

Impregnation of the concrete surface or the whole test specimen will not be included in the laboratory tests due to the fact that the Road Directorate do not prescribe this procedure anymore.

The contractors do not appreciate curing conditions where water is applied e.g. twice a day because it is not practical. The site will be too muddy and the method is not applicable in the winther time. Therefore this curing method is not included in the laboratory tests.

The different curing conditions will be tested on a typical concrete used for bridge constructions. The concrete choosen is the one used at several construction sites in Copenhagen at this time, 1995/96. The same concrete type is used in the HETEK project, part 3 and 4. In that project the mechanical properties of the concrete is tested.

The concrete has a maximum water-cement ratio of 0.40, low-alkali cement, fly ash, silica fume, seasand, granite and entrained air. The mix design is given in figure 2.2.

Figure 2.1: Test programme of the 14 curing tests

	Surface				
Test No	Form	Free surface	Curing Compound	10 mm DOW-matt	Wet surface
	mh	mh	mh	mh	mh
1	0 - 72	72 - 240	-	-	-
2	0 - 72	72 - 74	74 - 240	-	-
3****	0 - 240	-	-	-	-
4	-	0 - 240	-	-	-
5	0 - 24	24 - 240	-	-	-
6	0 - 24	24 - 26	26 - 240	-	-
7*	-	0 - 240	-	-	-
8*	0 - 72	72 - 74	74 - 240	-	-
9	-	0 - 4/8	4/8 - 240	-	-
10**	-	0 - 4/8	-	-	4/8 - 240
11	0 - 24	24 - 26	-	26 - 240	-
12	0 - 72	72 - 74	-	74 - 240	-
13	-	0 - 4/8	-	4/8 - 240	-
14***	-	0 - 4/8	4/8 - 240	-	-

All tests are performed in a period of 10 maturity days with the climatic conditions 3,6 m/s, 20°C and 70% RH. Afterwards the specimens are placed in a climate chamber with 20°C and 65% RH untill 28 maturity days are reached.

* At test no 7 and 8 the climatic conditions are 3,6 m/s, 20°C and 50% RH in a period of 10 maturity days.

** Without wind after 4/8 mh

*** Test no 14 has been defined after the first tests has been performed.

**** At test no 3 the evaporation of water from the curing will be tested too.

Figure 2.2: Concrete Mix design

Mix design		
	Type/origin/class	kg/m^3
Cement	Low-alkali Sulfatresistant CEM I 42,5(HS/EA/≤2)	285
Flyash	Danaske	60
Silica fume	Elkem	12
Water	Water	127
Fine aggregate	RN, Avedøre sand 0/4, SA	758
Coarse aggregate	Rønne granite 8/16, A	535
Coarse aggregate	Rønne granite 16/25, A	565
Air entrainment	Conplast 316 AEA	0,357
Plasticiser	Conplast 212	2,856
Superplastiser	Peramin F	1,428

The fourteen curing methods will be tested on a concrete specimen with a thickness of 100 mm and a surface of 550 x 450 mm. One half of the specimes will 28 days after casting be cut out in the different test specimens described below. When all fourteen curing methods have been tested the other half of the specimens will be placed outside in the field and exposed to Danish environmental conditions. DTI will make a field test area where the specimens can be kept for several years.

2.2 Testing of the Quality of the Concrete Surface

The quality of the concrete surface will be characterised based on the following five parameters:

- microcracks
- microstructure
- chloride penetration
- capillary water absorption
- carbonation

Details about each of the five parameters and the test methods intended to be used are given below.

Microcracks

Examination of the microstructure of the surface including amount of cracks, crack width, length and orientation and porosity evaluated by the variation in water-cement ratio. The test method will be TI-B 5, where a florescence impregnated thin section is analysed in microscope. Three thin sections , 30 x 45 mm, of each test specimens will be analysed.

Microstructure
If any differences in the surface structure is obtained by the test method TI-B 5 a SEMEX, Scanning Electro Microscopy analysis will be performed. The surface is tested on thin section covered with gold.

Chloride Penetration
The concrete resistance to chloride penetration will be tested using the ASTM C 1202-94 which is similar to AASHTOO 277-83 test method. The method gives information on the electrical resistance of the concrete expressed by the amount of Coulombs which pass through the test specimen. Two slices with a diameter of 100 mm and a thickness of 50 mm will be tested.

Capillary water Absorption
The concrete permeability will be tested using the capillary absorption test method TI-B 25. In this method concrete specimens are placed in contact with water and the ability to absorp water is measured as a function of the square root of time. The absorption is measured within a period of at least 4 days and until the difference between two weighings is less than 0.2 g (maximum 3 weeks). The capillary absorption will be tested on three specimens of 90 x 130 mm and a thickness of 30 mm.

Carbonation
The concrete resistance to carbonation will be tested using the NT BUILD 357 test method. The method gives information on the carbonation depth of concrete exposed to a concentration of CO_2 at 3,5%. The carbonation depth will be measured 1, 2 and 3 months after start of exposion. The resistance to carbonation will be tested on one specimen 100 x 100 x 300 mm.

3. Phase 2: Evaluation of Obtained Test Results and Establishment of Theory

The obtained test results from phase 1 will be evaluated in phase 2. The registered transport of moist from the test specimens will be described if possible based on the capillarity, permeability and diffusivity of the concrete.

Based on the results of the performed tests and the State of the Art report describing the existing knowledge about curing a theory will be performed. The theory will describe the correlation between the tested curing methods, the type of concrete and the obtained quality of the concrete surface. To verify the performed theory a number of extra tests will be planned and performed in phase 3.

If it is impossible to estimate a theory from the tests performed in phase 1 the results will be evaluated with care. From the evaluation the needs of supplementary research will be described. The supplementary research shall make it possible to prepare a guideline about curing.

4. Phase 3: Verification Tests

In this phase it is expected to perform 6 to 8 curing tests. All or some of the tests will be performed in the field to verify the theory performed in phase 2.

A detailed plan of phase 3 will be part of the report from phase 2.

The tests in the field will be performed on actual bridge constructions constructed by the contractors participating in this research project.

To verify the actual obtained climatic conditions in the field test period instruments will be placed on the surfaces chosen for testing.

The instruments are part of a mini-weather-station developed and tested by DTI. The mini-weather-station is able to measure the climatic conditions including temperature, wind velocity, direction of wind, relative humidity and daily rain fall.

The quality of the concrete surface layer will be characterisized after the principles stated in phase 1.

5. Phase 4: Evaluation and Establishment of Criteria for Approval

At the final evaluation it will be assessed if the performed theory has been verified by the tests performed in phase 3.

If possible conformity criterias for the concrete quality obtained by the contractors curing of high performance concrete will be set-up. The criterias will be based on the reported test results from phase 1 and phase 3.

6. List of Literature

Berrig, A. and Frederiksen, J.O.: "Måling af betonforseglingsmidlers virkningsgrad, Ny prøvningsmetode; TI-B 33"(in Danish, Determination of the efficiency of concrete curing compounds, New test method: TI-B 33). DTI report, November 1992.

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