HETEK

Pre-Testing of concrete properties and workmanship

Main Report and Guidelines

Report No.92
1997

Road Directorate Denmark Ministry of Transport

IRRD Information

Title in Danish	HETEK, Forprøvning af fremstilling af betonkonstruktioner. Hovedrapport og orienterende beskrivelse.
Title in English	HETEK, Pre-testing of concrete properties and workmanship. Main report and guidelines.
Author	Find Meyer
Subject classification	Concrete 32
Key words	Concrete 4755 High Strength 5537 Cast in situ concrete 4781 Contractor 0127 Dictionary 8596 Test Method 6288 Specification (standard) 0139 Research Project 8557 Denmark 8028
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. 7 concerns pre-testing. Pre-Testing is subdivided into 5 phases. The report contains a summary of the main results obtained in each of the phases. The guidelines for accomplishment of basic and additional pre-testings are described.
Front page photo	The front page photo shows the trial casting specimens which was cast as a part of the pretesting for The Gadholtvej Arch Bridge between Sæby and Frederikshavn, Jutland, Denmark built in high strength concrete and ordinary reinforcement.

Contents

0. Preface

Durability of reinforced concrete structures is in focus. Knowledge of relationships between durability and the composition of concrete has lead to development of high performance concrete with a long expected service life.

High Performance Concrete has significant resistance against deterioration both, when it is exposed to environmental conditions prescribed in the chosen test methods and when it is cast under Laboratory Conditions.

The aim is a similar resistance against deterioration for concrete cast in actual structures. Consequently, the requirements not only to the composition but also to the workmanship must be fulfilled. Experience shows, however, that the production properties for high performance concrete may result in severe difficulties in achieving the results required for the execution. Use of high performance concrete may change the conditions for choice of execution method.

Complicated structures with complex geometry and/or high reinforcement intensity may increase the execution difficulties. Previous experience is not always adequate when using high performance concrete.

Pre-testings performed before start of production castings can support the detailed planning of the execution.

The Danish Road Directorate has therefore arranged accomplishment of a development programme concerning the necessity for pre-testing, which has not previously been systematically described.

The programme is performed by a consortium composed of:

Dansk Betoninstitut A/S
DTI-Byggeri
Unicon Beton I/S

Jens Frandsen (4K-Beton A/S) has performed consultancy services.

The consortium is managed by:

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The work has been reviewed by Reidar Kompen, The Norwegian Road Directorate, who is a member of the technical committee associated with HETEK.

Feb. 1997

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1. Main Report

The development programme concerning Pre-testing consists of the following 5 phases:

1. State of the Art
2. Graduation
3. Test Panels and Exposure sites
4. Incorporation of results from other HETEK research programmes
5. Final report and Guide

The main results from each of the phases are described in the following.

For a more detailed description of the phases 1, 2 and 3 reference is given to the reports, which are appropriate at the Danish Road Directorate.

- HETEK - Report No. 40. Guide for Trial Castings. State of the Art.
- HETEK - Report No. 65. Pre-Testing of concrete, constituent materials, Composition and Workmanship
- HETEK - Report No. 84. Test Panels and Exposure Sites.

1.1 State of the art

This phase is performed by studies of the codes, standards and specifications which have been used during the decade.
Pre-testing may be classified at 3 different levels.

Pre-testing, Level 1:	Pre-testing without trial casting.
Pre-testing, Level 2:	Pre-testing by trial casting of minor plain concrete test specimens of 0.1-1.0 m^3.
Pre-testing, Level 3:	Pre-testing by trial casting of larger reinforced concrete specimens. The shape and reinforcement reflect the construction in question and the casting is carried out using the actual planned production methods.

The codes, standards and specifications which have been analysed and the related pre-testing levels are:

DS 411, Level 1:	Dansk Ingeniørforenings code of practice for the structural use of concrete - Dansk Standard DS 411. 3. Edition 1984. - 3. Issue 1988 and 6. Issue 1994.

BBB,	Level 2:	Basic Concrete Specification for Building Structures, BBB, published by The National Building Agency 1988 with later revisions.
AAB,	Level 2:	Tender and Construction precepts, Concrete Bridges, Ordinary Work Specification - abbreviated to AAB. The Danish Road Directorate 1985 with revisions 1989 and 1994.
NVB,	Level 2:	The Norwegian Road Directorate. Special work specifications for Aursundbrua and similar larger bridge structures.
SBF,	Level 3:	Ordinary and Special work specifications for the Great Belt projects - abbreviated to SBF. A/S Storebæltsforbindelsen 1988. The work specifications are based on AAB (85) but enlarged i.a. concerning required extent of trial castings.
ASØ,	Level 3:	Guidance in selection of concrete for the land based structures to the Øresund Link - abbreviated to ASØ. A/S Øresundsforbindelsen 1994. The Guide is based on AAB (89) but enlarged i.a. concerning required extent of trial castings.
ØSK,	Level 3:	Contract No. 1 - Tunnel. Construction Requirements Volumen 2. - Materials July 1995. (The document is confidential and cannot be made available on request or published).

In order to evaluate to which extent pre-testing by trial casting has served its purpose a number of civil works structures have been investigated. The investigations are carried out by interviewing contractors, concrete suppliers and supervision engineers who participated in the execution of the concrete works.

The main result of the investigations are shown in Tables 1.1 and 1.2.

Level 2	Contractor	Supervision engineer	Concrete supplier
The Guldborg Sund Tunnel	Less satisfactory	Less satisfactory	Satisfactory
The Brandstrupvej Bridge	Satisfactory	Satisfactory	Satisfactory
The Kjellerup East Bridge	Satisfactory	Satisfactory	Satisfactory
The Højbjerg Mølle-vej Bridge	Satisfactory	Satisfactory	Satisfactory
The Struer-Langå Railway Bridge	Satisfactory	Satisfactory	Satisfactory
The Bjerrevej Bridge	Satisfactory	Satisfactory	Satisfactory
The Kjellerup West Bridge	Satisfactory	Satisfactory	Satisfactory
Shelters, Aalborg Airport	Satisfactory	Satisfactory	Satisfactory
The Assentoft Bridge	Satisfactory	Satisfactory	Satisfactory

Table 1.1 *Pre-testing at level 2. The contractor's, the supervision engineer's and the concrete supplier's opinion on the benefit of trial castings.*

Level 3	Contractor	Supervision engineer	Concrete supplier
East Tunnel segments	Satisfactory	Satisfactory	Satisfactory
East tunnel Cut & Cover	Less satisfactory	Less satisfactory	Satisfactory
West Bridge Caissons	Less satisfactory	Less satisfactory	Satisfactory
West Bridge Road Girders	Less satisfactory	Less satisfactory	Satisfactory
Arch Bridge High strength concrete	Satisfactory	Satisfactory	Satisfactory

Table 1.2 *Pre-testing at level 3. The contractor's, the supervision engineer's and the concrete supplier's opinion on the benefit of trial castings.*

Based on these results it was concluded that a more differentiated graduation is needed to meet the contractor's demands concerning pre-testing of specific production methods such as e.g. vibration need.

1.2 Graduation

The purpose of this phase is a more differentiated graduation of pre-testings.

During the preparation of the report it appeared that there are two different opinions of the definition of a Trial casting.

The one opinion is that a Trial Casting is a casting of a reinforced concrete specimen with a shape reflecting the construction in question. The casting is carried out using the planned execution methods.

The other opinion is that a Trial Casting is an investigation of the properties of a trial mix. The investigation does not necessarily need to be carried out by casting of a concrete specimen.

In consequence hereof the concept of Trial Casting has not been used in the remaining part of the programme. Instead the more capacious designation "Pre-testing" is used.

The report contains definitions on often used terms related to pre-testing.

It is, of course, disadvantageous that there are different opinions of the definition of a Trial Casting - especially when it was the original title of the programme.

The title of the phase 2 report is: Pre-testing of concrete, constituent materials, composition and workmanship.

Pre-testings are divided into investigations performed by the concrete supplier and by the contractor. Experience shows that this division is also adequate, when the contractor is producing the concrete (usually only for significant concrete works). This is due to the fact that the requirements to the concrete production are independent quality assurance.
Furthermore the pre-testings are subdivided in a basic part, which is considered to be necessary for all structures, and additional testing which may be necessary for some structures.

The proposal for the concrete supplier's basic pre-testing comprises i.a. investigations of the basic design and production properties.

Additional testing may be related to e.g. resistance against chloride penetration and frost/thaw attack.

The proposal for the contractor's basic pre-testing comprises i.a. investigations of the vibration need for relatively simple structures. For this purpose a reinforced concrete standard test panel is designed.
Additional testing concerning workmanship is often related to difficult structural details. The report includes an overview of frequently occuring difficult details and

proposals for pre-testing. The report also contains estimated expenses for the basic pre-testings and the various additional testings.

1.3 Test panels and exposure sites

The Danish Road Directorate intends to place test specimens, so called test panels, at specific exposure sites, where they are exposed in different environments. The goal is to be able to estimate the resistance of panels against erosion in the chosen environments. The test panels are intended to be produced either as the standard test panels described i phase 2 with testing of recommended types of concrete for specific works, or with other types of concrete mixes, construction methods and/or panel design.

The exposure sites have been chosen so that they correspond to the normal environment either along motorways or by road bridges in Danish sea water.

The report is concerned with the test programme, the design of the test panels and the layout of exposure sites. The report also gives an estimate of expences related to 3 different types of test panels.

- Construction panels
- Laboratory panels
- Standard panels

The proposed design of the standard panel is identical with the test panel described in phase 2.

1.4 Incorporation of results from other parts of HETEK

The purpose of this phase is the incorporation of results from other parts of HETEK which are of importance for the pre-testing. The task is carried out on basis of comments and proposed additions received.

2. Introduction to the guide

2.1 Purpose

The purpose of the guide is to put the reader in a position to plan systematically the extent of necessary pre-testings.

The guide is primarily about structures performed with high performance concrete in aggressive environments. However the guide may also be used for more traditional structures.

Use of the guide presupposes knowledge of traditional concrete.

The pre-testings, which are dealt with, are:

- Pre-testing of concrete properties
- Pre-testing of workmanship

Guidelines are given for accomplishment of the pre-testings, extent of investigations to be made and how the result of the investigations can be used.

The guide does not include pre-testing of the constituent materials and includes, only to some extent, pre-testing of the concrete composition.

The guide comprises the task group proposal concerning qualitative investigations. Quantitatively stated dimensions and test methods are primarily based on The Danish Road Directorate's ordinary work specifications.

2.2 Previous knowledge

In some cases the concrete supplier and/or the contractor have well established knowledge about the concrete properties from previous works. This previous knowledge may totally or partly substitute the pre-testing. The guide describes when and to what extent this may be the case.

2.3 Background

The background material is the reports and investigations mentioned in section 1.

3. Definitions

The report makes use of some specific concepts:

Pre-testing:

Pre-testing is any kind of documentation of concrete, constituent materials, composition and/or workmanship, which is presented prior to production. The documentation can be based either on testing of the actual concrete or by documented knowledge from previous testing or casting.

Pre-testing of concrete properties:

Pre-testing of concrete properties is Pre-testing of design and basic production properties. Usually this Pre-testing includes the changes in production properties caused by transportation of the concrete from the mixing plant to the casting place.

Pre-testing of workmanship:

Pre-testing of workmanship is pre-testing of the suitability of the concrete assigned to casting of specific types of structures using specific production methods, or investigation of such additional production properties, which are not clarified during the pre-testing of concrete properties but which are in fact relevant for the structure in question and/or the planned execution method.

Trial Mix:

A trial mix is a mix with specific composition, which is used in the pre-testing.

Design properties:

The design properties of concrete are the properties, which are important for the use of the structure - for instance strength, elasticity and durability including the quality of the constituent materials and the W/C-ratio.

Production properties:

The production properties of concrete are the properties, which are to be paid attention to during production in order to ensure the specified design properties. The production properties are for instance workability, setting time and heat of hydration.

4. Elements of pre-testing

Differentiation between pre-testing of concrete properties and pre-testing of the workmanship will be applied in the following.

PRE-TESTING OF CONCRETE PROPERTIES.
This pre-testing includes necessary investigations concerning:

- The design properties of the concrete.
- The basic production properties of the concrete.

Basic productions properties include the production properties which are considered necessary to investigate for all civil work structure. The basic production properties are described in section 5.

Pre-testing of the concrete properties is performed by the concrete supplier. If the concrete is supplied by the contractor, the pre-testing is performed by the contractors concrete department.

PRE-TESTING OF WORKMANSHIP
Pre-testing of workmanship includes necessary investigations of the suitability of the concrete assigned to casting of specific structures using specific execution methods. Such investigations (which are often designated "Full Scale Trial Castings") are performed by the contractor, using concrete which has been accepted by pre-testing of the concrete properties.

Depending on the degree of complexity of the structure or on the production methods, further investigations of production properties, which are not included in the basic production properties, may be required. Such investigations of additional production properties are included under pre-testing of workmanship.

Investigations of additional production properties are carried out by the contractor and, depending on their nature, may be performed by the contractor himself or by the concrete supplier.
The additional production properties are described in section 6.2.

5. Pre-Testing of concrete properties

As mentioned in section 4, the investigations of concrete properties are related to:

- The design properties of the concrete
- The basic production properties of the concrete

The design properties include i.a.:
- W/C-ratio
- Chloride content
- Compressive strength
- Frost resistance
- Homogenity

The basic production properties include i.a.:
- Workability and loss of workability due to transportation
- Air content and loss of air in the fresh concrete due to transportation
- Bleeding after transportation
- Setting time
- Heat development during hydration
- Compressive strength development

The pre-testing of concrete properties is subdivided into.

- Basic pre-testing, which is necessary for all structures
- Additional pre-testing, which is required for some structures

5.1 Basic pre-testing of concrete properties

The basic pre-testing shall include investigations with a trial mix. The volume of the trial mix shall be equal to or larger than the batch size used for the subsequent production.

The trial mix concrete shall
- be subjected to the same methods of transport as planned for the execution. The concrete shall remain in the transportation equipment (usually drum mixer) for a determined period of time so that the subsequent transport, by means of pump, skip or rubberbelt conveyor, can be finished not earlier than 10 minutes before the planned maximum transport time.

- be investigated for design properties. The extent of testing is stated in Table 5.1.1.

- be investigated for production properties. The extent of testing is stated in Table 5.1.1.

Design properties	Comments	Guidelines for acceptance criteria
W/C-ratio	The W/C-ratio shall be determined on the basis of the quantities used for the trial mix. The Water content of the aggregates used for the trial mix shall be determined on bases of samples	The deviation in relation to the target value should be less than required for the production (usually ± 0.03).
Chloride content	Chloride content shall be determined by calculation using the mix design and the chloride content for each of the constituent materials. Measured or declared max. values may be used.	The chloride content shall be less than 0.2% by mass of powder. For structures exposed to chloride attack the content shall be less than 0.1% if not the structural design imply sufficient protection.
Compressive strength	Compressive 28 days strength shall be evaluated based on the strength development, Table 5.1.2.	The 28 days strength shall be sufficiently high in order to comply with the required characteristic strength for the production. Ref. DS 411 cl. 8.1.1.
Frost resistance	The hardened concrete shall be tested for air content and air void distribution. The test shall be performed on a cylinder ø 100 x 200 mm drilled from a test specimen with a volume of at least 0.1 m^3. Alternatively the test may be performed on a cast cylinder ø 150 x 300 mm. The test specimen (or cylinder) shall be cast using concrete from the trial mix after it has been transported by pump, skip or conveyor.	The air content shall be between 10 and 25% at the "kitmasse" and the specific surface at least 25 mm^{-1}. Test method e.g. TI-B4.
Homogenity	Concrete shall be determined for uneven distribution of coarse aggregates e.g. by means of test method DS 423.35.	The weight difference shall not exceed 0.1 kg.

Table 5.1.1. *Basic pre-testing of concrete properties.*
Design properties, extent and guidelines for acceptance.

Basic Production properties	**Comments**	**Guidelines for acceptance criteria**
Loss of workability and air content	Workability and air content shall be measured immediately after mixing and at least 3 times afterwards. The final measurement shall be made after the planned maximum time from mixing to final placing.	The loss of workability shall be adequate for compliance with the accept criterion for the production (usually ± 30 mm) using the planned maximum time from mixing to final placing. The air content after the planned maximum time for placing shall be at least 15% of the "kitmasse". If the concrete is expose to frost shall also the requirements to frost resistance for the hardened concrete be met. Ref. Table 5.1.1.
Bleeding	Bleeding shall be estimated after the concrete has been transported by pump, skip or conveyor.	Estimated visually the concrete should not indicate tendency of bleeding. If so the bleeding shall not exceed 0.5% (5 l per m^3 of concrete) after 4 hours. Test method e.g. DS 423.18.
Setting time	Setting time may be estimated based on to from the adiabatic or semiadiabatic calorimetry.	The contractor shall make sure that the setting time is adequate for the planned production methods.
Heat development	Heat development shall be measured by means of adiabatic or semiadiabatic calorimetry. The measurement may be performed using a separate mix which is smaller than the above specified trial mix.	The contractor shall make use of the determined values for the temperature development calculations.
Compressive strength development	Compressive strength development shall be determined on 4 sets of test cylinders after 1, 3, 7 and 28 maturity days. One set consists of 2 test cylinders.	The contractor shall make sure that the strength development is adequate for the planned production methods e.g. stripping of formwork and load capacity in the construction period.

Table 5.1.2. *Basic pre-testing of concrete properties.*
Basic production properties, extent and guidelines for acceptance.

5.2 Additional pre-testing of design properties

Depending on the static function, the complexity and/or the environmental exposure of the structure, it may be necessary to perform further investigations in addition to investigations into basic design properties, Table 5.1.1.

Additional investigations are typically related to resistance against deterioration caused by chloride penetration and frost/thaw attack and to exclusion of early-age cracking. The latter investigation may be performed as a part of the additional pre-testing of production properties - ref. section 6.2. Samples for testing of the resistance against chloride penetration and frost/thaw attack may be cast cylinders or cores cut from the standard test specimen (ref. section 6.1) or cores cut from test specimen of specific structural details (ref. section 7).

The necessity of such extended pre-testing, test methods and acceptance criteria is described in other HETEK programmes. Reference is made to:

- Method for test of the Frost Resistance
- Chloride penetration into concrete
- Control of Early-age cracking

The concrete density should be investigated in case of significant variation in aggregate density.

5.3 Previous knowledge

Pre-testing of concrete properties may be omitted if it can be documented that investigations of the required production and design properties have been made recently (usually within one year), and that the concrete has previously been used for execution of a similar structure.

The constituent materials shall be of same origin. The type and size of mixer shall be unchanged and the conditions for production shall be the same.
It should, however, be documentet that the loss of workability, loss of air content and the strength development (at least to 7 days) are unchanged.

6. Pre-Testing of workmanship

Pre-testing of workmanship includes investigations necessary to demonstrate that the concrete is suitable for execution of a specific structure with the planned execution methods. Such investigations (often named "full scale trial casting") are carried out by the contractor using concrete which has been accepted by pre-testing of concrete properties (see section 5).

As mentioned in section 5, the pre-testing of concrete properties includes only investigation of the basic production properties.

Investigation of additional production properties may be required depending on the degree of complexity of the structure and/or on the production methods. Such investigations of additional production properties are included in this section.

Pre-testing of workmanship is subdivided into:
- Basic pre-testing, which is required for all structures
- Additional pre-testing of production properties, which is required for some structures

Pre-testing of specific structural details is dealt with in section 7.

6.1 Basic pre-testing of workmanship

The basic pre-testing of workmanship should describe additional production properties. These are normally:

1. Poker vibration including the influence of reinforcement
2. Temperature development in the structure

The investigations are performed using a relatively simple structure. The standard test specimen is shown on Fig. 6.1. The dimensions are 1.2 x 1.2 x 0.6 m. The reinforcement is shown on Fig. 6.2 and corresponds to normal reinforced structures with a reinforcement of approximately 100 kg/m³. The four reinforcement bars ø 10, shown on detail 1 and 2, are placed only if the test specimen is to be used for long term durability testing - ref. report No. 84. The formwork may be carried out as shown on Fig. 6.3 and thermo couplers are placed as shqwn on the same Fig. 6.3.

The basic pre-testing of workmanship may be carried out with the trial mix used for pre-testing of the concrete properties. If, however, the latter fails then the basic pre-testing of workmanship has also to be repeated.

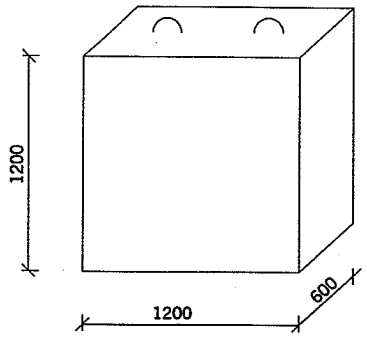

Fig. 6.1 Basic pre-testing of workmanship.
Standard test specimen.

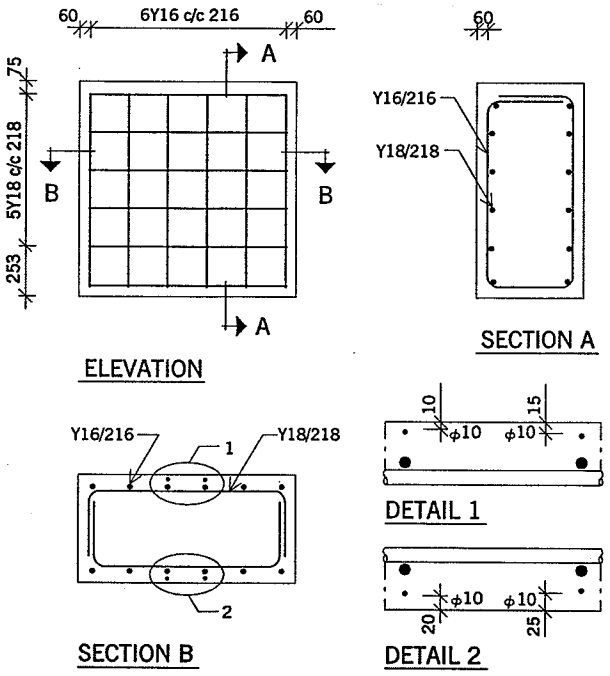

Fig. 6.2 Basic pre-testing of workmanship.
Reinforcement. Measures to center of bars.
Concrete cover + tolerance: 50 +5 mm for vertical faces 1.2 x 1.2 m.

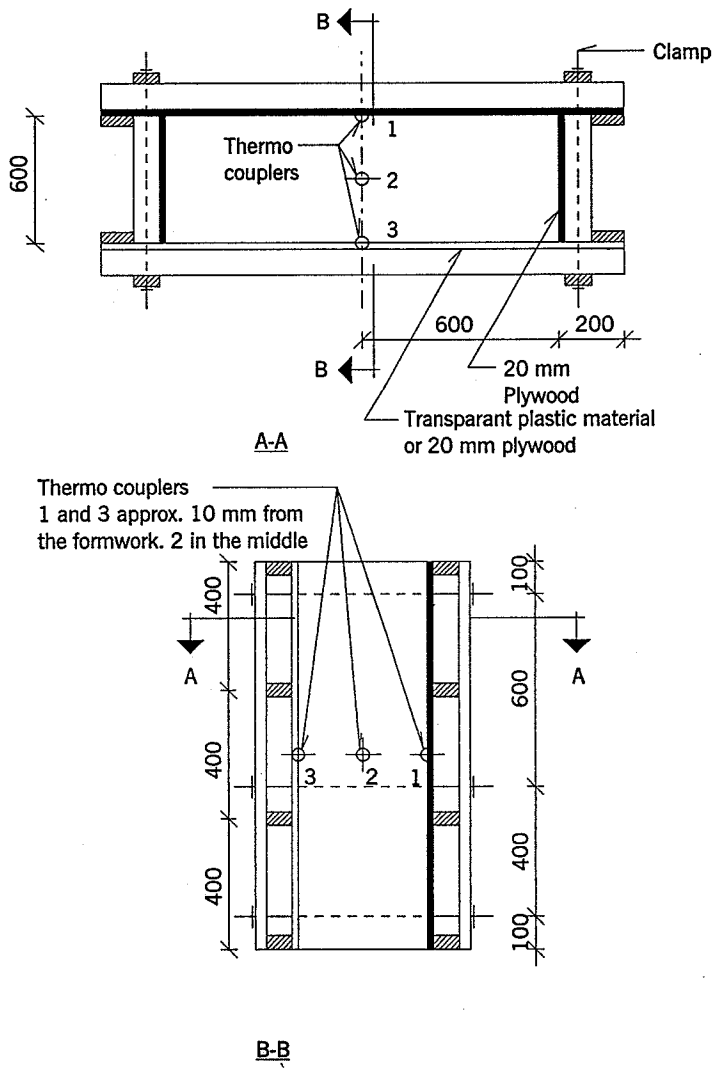

Fig. 6.3 Basic pre-testing of workmanship. Standard test specimen. Formwork and placing of thermo couplers.

6.1.1 Poker vibration

The effect of the poker vibrators shall be investigated during casting of the standard test specimen. The following parameters shall be established:

- thickness of casting layers
- vibration time
- insertion distance

Criteria for selection of these parameters are discussed in "Recommendation for Poker Vibration".

For the selected size of poker vibrator and concrete slump the parameters may be estimated by using Fig. 6.4 and Table 6.5. For the reinforcement used in the test specimen shown in Fig. 6.2, the insertion distance may be assumed to 8 · d (d is the diameter of the poker vibrator). The thickness of the concrete layers must not exceed 80% of the length of the selected poker vibrator. The test specimen is executed based on the estimated parameters.

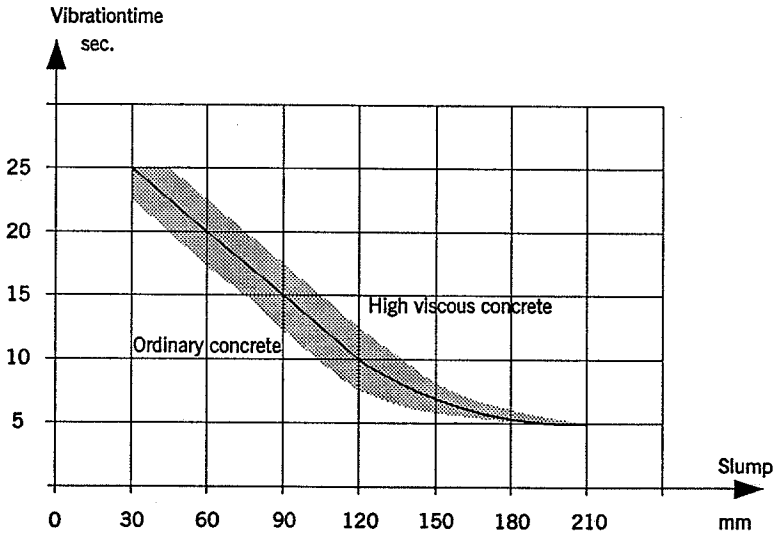

Fig. 6.4 Relation between vibration time and slump.

Degree of complexity	**Example**	**Insertion distance a = n·d**
1 Simple	Plain concrete and low steel percentage	10 d
2 Normal	Usual steel percentage	8 d
3 Difficult	High steel percentage and some congested areas	6 d
4 Very difficult	As 3 but many congested areas	4 d
5 Extremely difficult	Should not be used	2 d

Table 6.5 Relation between the insertion distance and the degree of complexity.

One side of the formwork may be of a transparent plastic material. In this manner the movements of the coarse air bubbles may be observed during vibration, and thus assist the selection of the 3 parameters.

After stripping the concrete surfaces shall be inspected visually for defects and extent of blow holes. The in depth vibration effect on the concrete shall be investigated on drilled cores. The investigations should include air void analysis.

Acceptance criteria:
- The vertical surfaces should not reveal more than 22 blow holes with diameter and/or depth above 5 mm and no honeycombs.
- For concrete exposed to frost/thaw attack the drilled cores shall be investigated as described Table 5.1.1. Alternatively the concrete can be examined as described in "Method for test of the Frost Resistance".

The establishment of the 3 parameters:
- thickness of concrete layers
- vibration time
- insertion distance

to be used for production castings should be based on the obtained test results. Adjustments may be expected for complex structural details.

6.1.2 Temperature development

Prior to casting of the standard test specimen, thermo couplers shall be placed in the middle and in the surfaces as indicated Fig. 6.3.
Prior to casting, the expected temperature development shall also be calculated at the above mentioned points.
The calculations shall be based on the heat development (re. section 5.1) and the time for stripping of the formwork. The fresh concrete temperature and the outdoor temperature may be estimated based on the weather forecast.
During hardening, the temperature shall be registrated frequently so that the actual heat development can be compared with the calculations. Of special interest are maximum temperature in the middle of the test specimen and maximum temperature difference between the middle and surface. The latter temperature difference must not exceed 20°C in the actual structures.
To ensure representativity the temperature difference in the test specimen should consequently not exceed 20°C.

If there are significant deviations between the registrated and calculated temperatures, the reasons shall be found and necessary adjustments taken to ensure realistic assumptions for the production castings.

It should be emphasized that the pre-testing of the heat development as outlined above is only of a preparatory nature.

The specific conditions for production castings are usually much more complex than for the standard test specimen. This is, for instance, the case when a structural part shall be cast against a previous structure. A crack-free standard test specimen must therefore not be considered as an indication of crackfree production castings in general.

6.2 Additional pre-testing, production properties

Depending on the complexity of the structure, the execution method and/or the mix design it may be necessary to perform additional pre-testing of production properties which were not investigated during basic pre-testing. This section

describes examples of such additional pre-testings and when they are assumed to be necessary.

6.2.1 Additional pre-testing of high reinforcement percentage

The purpose of this additional pre-testing is to establish the 3 parameters for poker vibration for structures having significantly higher reinforcement percentages than the standard test specimen Fig. 6.2.

The investigations may be performed as described section 5.1.1 by changing the reinforcement (ref. Fig. 6.2) to the percentage in question. Acceptance criteria are as described section 5.1.1.

6.2.2 Additional pre-testing of production properties related to early age stress calculations

The purpose of this additional pre-testing is to investigate the additional production properties required for calculation of the early stresses in the hardening concrete. Such calculations may be required e.g. in cases of strict requirements to the temperature difference between neighbouring, previously cast concrete and fresh casts. Calculations based on the additional production properties can document the temperature criteria which may be used.

The relevant additional production properties are:

- Thermal expansion coefficient, e.g. test method TI-B101
- Early-age shrinkage and creep, e.g. test method TI-B102
- E-modulus development, e.g. test method NT BUILD 205
- Splitting tensile strength development, e.g. test method DS 423.34

The investigations shall be performed using concrete from the trial mix (ref. section 5) or from a smaller similar mix.

6.2.3 Additional pre-testing of early-age stress calculations

The purpose of this additional pre-testing is to test the early-age stress calculations by casting a test specimen using the precautions assumed in the stress calculations.

The distance between cracks which may occur due to restraint deformations is generally approx. 4 m. The test specimen shall consequently be at least 8 m long to reflect the real conditions.
The total volume for instance for pre-testing of a wall with a cross-section 3.5 x 0.6 m on a foundation slab with dimensions 1.0 x 3.0 m will be approx. 30 m^3.
Only one set of parameters e.g. fresh concrete temperature, insulation, stripping time and outdoor temperature can be investigated. Protection against early age cracking in the production casting can therefore in general not be estimated by this pre-testing.

Consequently such additional pre-testings are not usually carried out.

6.3 Previous Knowledge

The basic pre-testing of workmanship (section 6.1) may totally or partly be omitted if it can be documented that the required investigations have already been made and the concrete has previously been used successfully for the execution of a similar structure.

7. Pre-Testing of structural details

The purpose of pre-testing of structural details is to investigate whether the concrete is suitable for casting specific complex structures or structural details.

The investigation is performed by casting a test specimen which reflects the complexity of the structure in question. The casting should be carried out using the planned execution method.

The structures or structural details which are recommended to be investigated are described in "Guide for structural design and workmanship".

The structures are e.g.:

7.1 Structures with high reinforcement percentage, prestressing anchors and cast-in items including cooling pipes.
7.2 Structures with a significant number and/or size of box-outs.
7.3 Structures with cavity tubes.
7.4 Structures with inclined surfaces cast against formwork.
7.5 Structures with inclined surfaces cast without formwork.
7.6 Structures with high walls or columns.

In addition pre-testing for:

7.7 Underwater casting.
7.8 Slipform casting.

are described.

The guide for structural design describes methods for the execution of the above mentioned structures.
Pre-testing is however recommended if the concrete gang has little or no previous experience from similar works carried out with high performance concrete.

Pre-testing of structural details are not usually carried out for minor civil works structures. If, however, the work includes structural details as mentioned and if they are of significant importance it may be necessary.

For large civil works structures with 5-10,000 m^3 of concrete at least one of the structural details should be pre-tested.

The acceptance criteria are:

- The test specimen should be without visible casting defects.
- Correct concrete cover should be tested by use of a cover meter.
- Concrete cores can be cut for determination of the required resistance against chloride penetration and frost/thaw attack.

7.1 Pre-testing of High reinforcement percentage, prestressing anchors and cast-in items including cooling pipes

The actual reinforcement, the prestressing anchors and the cast-in items can be placed in a test specimen of equal or larger dimensions as the specimen shown on Fig. 6.1.

7.2 Pre-testing of Box-outs

Pre-testing of large box-outs requires a test specimen which is larger than the standard test specimen (Fig. 6.1). There should be at least 1 m from the edge of the specimen to the box-out. If the box-out is for instance 1 m long the length of the test specimen should be at least 3 m.

7.3 Pre-testing of Cavity tubes

Investigations concerning casting methods for slabs or beams with cavity tubes require test specimens of significant horizontal extension. This is necessary in order to examine the buoyancy and possible deformations of the cavity tubes using the planned casting sequences.
This kind of pre-testing is not usually carried out.

Further information concerning execution methods can be found in "Guide for structural design and workmanship".

7.4 Pre-testing of inclined surfaces cast against formwork

The height of the test specimen for investigations of inclined surfaces cast against formwork shall reflect the actual cross section. This is necessary in order to examine the effect of the planned vibration technique.
Especially the difficult vibration underneath the inclinated formwork (see Fig. 7.1) ought to be tested if the concrete gang has no previous experience from similar castings carried out with high performance concrete.

Further information concerning execution methods can be found in "Guide for structural design and workmanship".

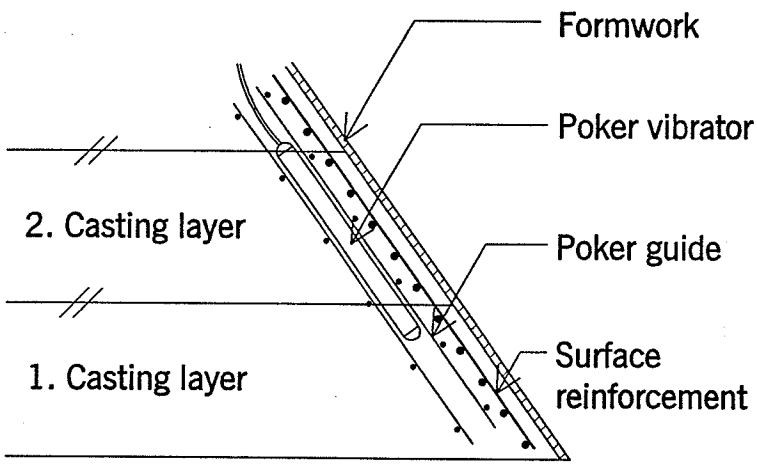

Fig. 7.1. Vibration underneath inclined formwork.

7.5 Pre-testing of inclined surfaces cast without formwork

The test specimen for investigation of inclined surfaces cast without formwork may be a slab with thickness 0.3 m. The length and width can for instance be 3 x 3 m.

The planned production methods, including equipment and evaporation protection, shall be investigated during execution of the test specimem.

The production methods may be:

- poker vibration
- beam vibration
- screeding
- manual floating
- finishing machines (not recommended ref. Guide for use of high performance concrete, The Danish Concrete Institute, 95)

The evaporation protection may be performed using:

- covering with waterproof membrane
- covering with waterproof insulation mats
- application of curing compound

7.6 Pre-Testing of high walls or columns

Execution of high walls and columns using relatively high casting rate and/or intensive vibration may lead to significantly reduced air content in the lower part of the wall due to the high pressure.
If the wall or column is exposed to frost/thaw attack it may be necessary to investigate by pre-testing the connection between casting rate, vibration intensity and air content.
The test specimen should be of the same height and thickness as the actual structure. The length should correspond with at least 2 m of the wall.

The planned casting rate and vibration technique shall be used for casting the test specimen.

The air content in the lower part shall be investigated on cores drilled out.

7.7 Pre-testing of Underwater casting

The purpose of this pre-testing is to test whether the concrete is suitable for underwater casting. Underwater castings are usually carried out without vibration of the concrete and it is therefore of significant importance to investigate the additional production properties concerning:

- flowing out, spread or viscosity
- internal cohesion

It should also be ensured that the execution method results in a homogene concrete without detrimental cavities.
The spread of the concrete may be tested by test method NT BUILD 194.
The viscosity and cohesion (yield stress) may be tested by means of a Rheometer. The method is described in "Guide for use of high performance concrete" [The Danish Concrete Institute 1995].

Investigation of the execution method may be performed by casting a test specimen in formwork placed under water. The formwork shall be reasonably long to reflect the real structure and to examine the flow of the underwater concrete.
The length can be for instance 4-5 m. The height and width may be reduced to 1.0 x 0.6 m. Some of the concrete may be coloured in order to clarify the concrete movements during casting.

The 6 tons test specimen should be brought on shore after hardening. Investigations of cavities may be performed by drilling out cores.
It should also be decided whether the character of the upper surface concerning irregularity is suitable for the actual purpose.

The pre-testing described above is not usually carried out unless the structure is of significant importance for the process of construction and/or for the durability and strength.

7.8 Pre-testing of slip form casting

The purpose of this pre-testing is to investigate additional production properties which are of importance for slip form castings. A number of investigations have revealed a greater extent of microdefects for slip form castings compared to structures cast against fixed form. The influence of the micro defects, as far as durability is concerned is not known with certainty - but it should be taken into consideration during planning.

Concrete mixes with long setting time, significant stickiness and tendency to crust formation may lead to difficult execution of slip form castings. These additional

production properties (stickiness and crust formation) are described in "Guide for use of High Performance Concrete" [The Danish Concrete Institute, 1995].

Test specimens for investigation of the slip form method should be of significant size, in order to form a realistic basis which can be used for production.
The front page photo on the State of the Art report shows the test specimens which were cast as a part of the pre-testing for the slip form casting of the Great Belt West Bridge caissons.
The volume of the test specimen was approx. 40 m^3.
The expenses are significant and such additional pre-testings are not usually carried out.

The influence of the concrete composition regarding the additional production properties, stickiness and crust formation, should however be estimated.
The planning of thickness of casting layers and slip form speed may then be based hereon and on knowledge about the setting time which is investigated by pre-testing of concrete properties (ref. section 5). Also the climatic conditions (temperature, wind and humidity) and their influence on the production properties should be taken into consideration.
Further information can be found in "Guide for use of High Performance Concrete" [The Danish Concrete Institute, 1995].

8. References

HETEK Report No. 40: Guide for Trial Castings, State of the Art, The Danish Road Directorate 1996.

HETEK Report No. 65: Pre-Testing of concrete, constituent materials, composition and workmanship. The Danish Road Directorate 1997.

HETEK Report No. 84: Test Panels and Exposure Sites. The Danish Road Directorate 1997.

The Danish Concrete Institute, 1993: High Performance Concrete for exposed Civil Work Structures, State of the Art.

The Danish Concrete Institute, 1995: Anvisning i brug af højkvalitetsbeton til udsatte anlægskonstruktioner, in Danish (Guide for use of High Performance Concrete).

Frandsen, S. and Schultz, K.I.: Vibrering med stavvibrator, vejledning, in Danish (Guide for poker vibration), The Danish Concrete Institute 1995.

Vejregeludvalget: "Udbuds- og anlægsforskrifter - Betonbroer - Almindelig arbejdsbeskrivelse (AAB)", in Danish (Tender and Construction Precepts - Concrete Bridges - Ordinary work specification), Vejregler, December 1994.

ATV-udvalget vedrørende betonbygværkers holdbarhed: "Basisbetonbeskrivelsen for bygningskosntruktioner (BBB)", in Danish (Basic Concrete Specification for Building Structures), National Building Agency, march 1987.

ATV-udvalget vedrørende betonbygværkers holdbarhed: "Redegørelse vedrørende Basisbetonbeskrivelsen" in Danish (Explanatory Document to BBB), The Academy for Technical Sciences, May 1986.

Dansk Ingeniørforenings code of practice for the structural use of concrete - Dansk Standard DS 411. 3. Edition 1984. - 3. Issue 1988 and 6. Issue 1994.

Enclosure 1: Checklists.

5. Pre-Testing of concrete properties

5.1 Basic pre-testing of concrete properties

5.1.1 Design properties (Table 5.1.1)

- W/C-ratio
- Chloride content
- Compressive strength
- Frost resistance
- Separation
- Other

5.1.2 Basic production properties (Table 5.1.2)

- Loss of workability
- Loss of air content
- Bleeding
- Setting time
- Heat development
- Compressive strength development
- Other

5.2 Additional pre-testing, design properties

- Frost/thaw resistance
- Resistance against chloride penetration
- Concrete density

6. Pre-Testing of workmanship

6.1 Basic pre-testing of workmanship

- Test specimen 1.2 x 1.2 x 0.6 m (Fig. 6.1)
- Placing of reinforcement (Fig. 6.2)
- Placing of thermocouplers (Fig. 6.3)

6.1.1 Poker vibration

- Size of poker vibrators
- Planned workability
- Vibration time (Fig. 6.4)
- Insertion distance (8 x the diameter of the poker vibrator)
- Thickness of casting layers (80% of the length of the poker vibrator)
- Casting of test specimen
- Velocity of coarse air bubbles if transparent formwork is used
- Visuel inspection. Number of blow holes with diameter and/or depth above 5 mm (max. 22)
- Drilling of cores for determination of air content and specific surface

- Drilling of cores for alternative investigation of frost/thaw resistance
- Establishment of thickness of concrete layer, vibration time and insertion distance for the production castings

6.1.2 Temperature development

- Estimated outdoor temperature
- Estimated fresh concrete temperature
- Heat development parameters (cl. 5.1.2)
- Time for stripping of the formwork
- Calculation of the temperature development for the points where thermo couplers are placed
- Recorded temperature development
- Accordance between calculated and recorded temperatures
- Recorded and calculated temperature difference between middle and surface
- Corrections

6.2 Additional pre-testing, production properties

6.2.1 Additional pre-testing of high reinforcement percentage

- Reinforcement percentage $>>$ 100 kg/m^3
- Casting of test specimen
- Establishment of thickness of concrete layer, vibration time and insertion distance for the production castings

6.2.2 Additional pre-testing of production properties related to early-age stress calculations

- Thermal expansion coefficient
- Early-age shrinkage and creep
- E-modulus development
- Splitting tensile strength development

6.2.3 Additional pre-testing of early-age stress calculations

- Casting of test specimen

7. Pre-Testing of structural details

7.1 Structures with high reinforcement percentage, prestressing anchors and cast-in items including cooling pipes

- Casting of test specimen

7.2 Structures with a significant number and/or size of box-outs

- Casting of test specimen

7.3 Structures with cavity tubes

- Casting of test specimen

7.4 Structures with inclined surfaces cast against formwork

- Casting of test specimen

7.5 Structures with inclined surfaces cast without formwork

- Casting of test specimen

7.6 Structures with high walls or columns

- Casting of test specimen
- Air content and specific surface

7.7 Underwater casting

- Casting of test specimen

7.8 Slip form casting

- Casting of test specimen