

DANISH APPROACH TO SOLVING CONCRETE DURABILITY PROBLEMS



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Synopsis

A number of Danish Research Institutes and private companies have participated in a four-year (1982-86) long campaign, in order to obtain a longer durability of new concrete structures, and to promote a higher degree of maintenance of existing concrete structures. The content of the campaign is described

CONSEQUENCES ARISING FROM THE PAST

What Went Wrong?

During the late 70'ies an increasing number of durability problems were registered in Danish concrete structures. The expenses for repair and maintenance increased accordingly, and the reputation of concrete as a durable building material, and thus its suitability for a number of important purposes was seriously questioned.

On this background the Danish Council of Technology and the Danish Council for Scientific and Technical Research initiated an analysis of the nature and extent of the problem. The analysis confirmed that the economic extent of the durability problem was such that special efforts could be justified, even if the analysis showed, that the increasing repairs could be related to a heavy increase in the application of concrete during the preceding years, not least in exposed structures such as access balconies and swimming pools.

The analysis also revealed that the insufficient durability (much too) often is due to relatively simple mistakes. Lack of basic knowledge may very well make it difficult to select the optimum solution, but the sensible use of existing knowledge could have prevented or at least reduced many of the damages.

It Must Not Happen Again

Subsequently, The Danish Academy of the Technical Sciences (ATV) and the Danish Concrete Association initiated a number of activities over a period of four years, the purpose being to obtain a longer durability of new concrete structures and also to promote a higher degree of maintenance of existing concrete structures. This paper contains a short description of - and reason for - the activities.

The result of the analysis showed that the activities especially should contribute to an improved utilization of accessible knowledge in general design and construction practice. The types of activities were discussed and given priority by a committee consisting of a large number of individuals with quite different professional and commercial backgrounds.

Within the four-year period, projects to a total value of about DKK 20 mill. (2.5 mill. US-dollars) have been initiated. The Council of Technology has contributed ab. DKK 11 mill., the Research Council ab. DKK 1 mill., and the remaining ab. DKK 8 mill. have been paid by other public and private sponsors, partly through their participation in the projects at no charge.

An overall survey of the projects in progress is given in figure 1. Figure 2 gives the names of the institutes or companies directly responsible for the individual projects. A couple of the projects have been performed primarily in support of the ATV-Committee's own priority work, and will not be discussed further. A series of the other projects have had the primary goal of making it easier to apply existing knowledge, whereas others contain regular research aspects.

Project	Responsible agency	Project	Responsible agency
Even concrete needs maintenance	5	Alkali reactivity of fine aggregate * by chemical shrinkage method	9
Concrete inspection procedures	13	Gel formation in alkali - silica reactions	* 13
Simple concrete repairs	5	Requirements on concrete aggregates *	13
Preventive surface treatment of concrete	* 14	Thin section microscopy of concrete *	13
Concrete swimming pools	* 6	Water content of fresh concrete	3
Typical procedures for renewal of access balconies	2	Simultaneous moisture and heat transfer	* 3
NDT methods to assess the state of maintenance	* 2	Design of balconies and other exposed concrete structures	3
Critical chloride content of concrete	* 8	Concrete in-service training	1
Field study on Brøndby Strand	4	Better concreting on site	11
Particular requirements on durable concrete	13	Survey of knowledge transfer	10
Standard concrete specification	5	Industrial curing technology	3
Plastic shrinkage	* 3	Framework for quality assurance	3
Accelerating effect of alkalis on alkali-silica reactions	* 13	Review of existing QA-activities	13
Petrographic method for evalua- ting alkali reactivity of sand	* 13	Concrete deterioration	12
		13 concrete diseases	7
		Corrosion handbook	8

Figure 1. Overall survey of the projects.
* Projects involving research.

Responsible agency		Responsible agency	
Beton EU P.O.Box 326, DK - 2800 Lyngby	1	Danish Corrosion Center Park Alle 345, DK - 2605 Brøndby	8
Center for Building Planning Systematics P.O.Box 149, DK - 2970 Hørsholm	2	The Danish Technical University, Institute of Mineral Industry Lundtoftevej 100, DK - 2800 Lyngby	9
Concrete and Structural Research Institute P.O.Box 82, DK - 2970 Hørsholm	3	B. Kold Larsen A/S Arbusgade 11-13, DK - 2100 Kbhvn Ø	10
COWI Consult A/S Teknikerbyen 45, DK - 2830 Virum	4	Lemming & Eriksson A/S Lundtoftevej 1 F, DK - 2800 Lyngby	11
Danish Academy of the Technical Sciences Lundtoftevej 266, DK - 2800 Lyngby	5	Registry of Errors in the Building Process Gunnækær 60, DK - 2610 Rødovre	12
Danish Association for the Technology of Swimming Pools Gregersensvej, DK - 2630 Tåstrup	6	Technological Institute Building Technology Gregersensvej, DK - 2630 Tåstrup	13
Danish Building Research Institute P.O.Box 119, DK - 2970 Hørsholm	7	Technological Institute Surface Coatings Technology Gregersensvej, DK - 2630 Tåstrup	14

Figure 2. Responsible institutes and companies.

KNOW-HOW ON NEW STRUCTURES

Adjustment of Existing Knowledge

The concrete specifications which determine the quality requirements to materials and execution in the everyday practice, in reality express how the existing concrete know-how - at best - is used. The execution process can lead to a poor structure despite a good specification, whereas the opposite is unlikely. Within Danish practice up till now, substantial differences can be registered between the requirements used in various concrete specifications, even if the buildings in actual fact are alike. Existing knowledge has in actual practice been understood and interpreted differently. Apart from the direct mistakes resulting from an insufficient specification, the diverging specifications have no doubt reduced the respect for the established requirements with the contractors. The ATV-committee estimated that a greater uniformity within the specifications of the individual structures would contribute substantially to an improved quality and to the elimination of mistakes, and they therefore started the preparation of a standard concrete specification (BBB) which should be phrased in such a manner that it can serve without change as part of the legal contract covering an individual construction job.

It is quite simple to define the requirements to good concrete, because the use of conservative specifications can compensate for lacking basic knowledge. Uncertainty within the basic knowledge

however, makes it a good deal more difficult to define the requirements, which are necessary to obtain sufficiently good concrete. The preparation of the BBB has therefore especially been an act of balance between the desirable degree of conservatism on one side, and the consequences to resources and economy on the other side. It has been emphasized that this balance, to the greatest extent possible, should comply with the views expressed by the various involved parties, the purpose being for instance to make a possible demand for the compulsory use of the specification in all construction receiving public support acceptable.

The standard concrete specification represents a substantial improvement in the procedures for quality assurance of the concrete material. Attempts are made to follow up on this improvement through the development of other aids, to be used to assure the quality of design and execution. A recommendation is being prepared for the design of concrete balcony structures. These structures may in many respects serve as an example of the general problem of severely exposed structures. By means of proposals to detailing as well as check lists to be used at various stages in the process, the designer as well as the contractor will be supplied with various aids, in order to avoid a number of the structural mistakes, which typically have lead to reduced durability.

Moreover, the project 'Better Concrete Work at the Building Site' aims at systematizing the effort, which can be done at the individual building site, in order to motivate each worker to a greater quality awareness, for instance through an improved cooperation between designer and contractor. This coordination should allow for the different types of organisation, which can be used, when a number of various companies have to cooperate on a construction job.

Transfer of knowledge

As appears above, the mentioned projects re-phrase the existing professional knowledge with the purpose of making it more easily applicable in practice. Moreover, other initiatives have been taken in order to make the transfer of knowledge more effective.

The five largest institutions offering in-service training for civil engineers, are about to produce a substantially better coordinated selection of courses, among other items based on a joint modular training material, (Concrete-EU). At the same time, it is attempted to create a better motivation for the in-service training, through a better connection between the courses and the participants' actual job situations. A number of the other projects can provide valuable basis for training materials as well as regular courses. This applies for instance to the standard concrete specification.

Within the project "Practical concrete technology" AV-materials, illustrative leaflets and posters are prepared for use in the training of skilled workers. The participants in this project are a number of organizations together with the Branch Association for Building Works for the Education of Skilled Workers.

The improved in-service training is a necessary condition for a better implementation of the existing knowledge. On top of that, however, it often requires changes involving other persons besides the ones who just attended the course. It could be changes in production equipment, in normally applied standard solutions, or in established work and cooperation routines. Within a specific area (industrial curing technology), a number of barriers were registered in three individual companies, which made it difficult to introduce such changes. An active engagement on the part of the management can be required. To that end, the managements, may have to give the same degree of attention to technical problems as they give to finances and legal matters. Moreover, the organizations offering the courses may have to provide motivation not only to the potential course participants, but also to the decision makers who have the authority to reduce the barriers.

Improvement of Basic Knowledge

Even if the experiences from the concrete damages have indicated, that the reason for the damage mostly is lacking application of existing knowledge rather than lacking knowledge, the ATV-committee, however, has decided to start a number of more traditional research projects. Most of them have the specific aim of removing or reducing the uncertainties behind the provisions in the standard concrete specification. This applies to the project "Aggregates for concrete" and four projects on alkali-silica reactions. At the same time, these projects should contribute to the best possible utilization of accessible resources, and relevant test methods should be established.

The projects "Water contents of fresh concrete" and "Thin section microscopy of concrete" deal with the possibilities of assuring the quality of the concrete mix and - casting. Both the water contents and the paste structure can be measured with sufficient accuracy, but the result cannot be used for operative purposes, because it becomes available too late, and only little guidance can be given on how to obtain a required paste structure by monitoring factors, that are more readily under the control of the contractor.

Finally the projects "Plastic shrinkage" and "Simultaneous heat and moisture transfer" aim at a better determination of the curing conditions to be satisfied in order to obtain the needed, initial concrete quality.

KNOW-HOW ON REPAIR AND MAINTENANCE

Concrete must be maintained.

Limited maintenance is often able to prevent the need for thorough repairs. At an early stage the ATV committee therefore presented the recommendations "Even concrete needs maintenance" and "Concrete inspection procedures" with the purpose of

motivating owners and administrators of concrete structures to provide a maintenance function, and to assist the operating personnel to effect the necessary inspections. These activities are followed by a course being offered under the auspices of the Federation of non profit housing in Denmark. Moreover a report "Simple concrete repairs" provides recommendations to be used primarily by small contracting firms, with a limited experience in repair works.

- But How?

The question of repairs is difficult to deal with, because so far only limited possibilities exist to foresee the rate of the deterioration process in any given structure, and to what degree this rate depends upon the repairs being done - if any at all. Therefore an economical evaluation over some years, dealing with the repairs and maintenance of a structure, will often be subject to great uncertainty. Furthermore a number of new enterprises and materials have turned up in the growing market for repair works, so it is no wonder that it can be difficult - especially for owners of buildings without their own technical staffs - to distinguish between serious and non-serious advisors and repair companies.

On this background, the committee has decided to support two projects which deal with two types of structures, i.e, access balconies and swimming pools. For each type, recommendations are prepared containing typical repair methods, related to the registered condition of the structure. For the access balconies, the first recommendation was based on already existing knowledge. In a second stage, a more thorough examination of the applicability of the various inspection methods is being prepared.

In both projects representatives for building owners, advisors as well as contractors have participated, the purpose being partly to obtain the best possible professional balance, and partly to contribute to a subsequent easier implementation of the project results.

Along with these activities, two projects have been started which will discuss the possibilities of stopping concrete deterioration. The project "Preventive surface treatment of concrete" thoroughly deals with the protection of concrete against carbonation, whereas a parallel project deals with the protection against physical deterioration, especially caused by frost and thaw.

Finally a separate laboratory study has been initiated into the maximum chloride contents, which can be accepted in a concrete structure before the reinforcement starts corroding. This question has turned out to be a common problem in evaluating the condition of a number of different concrete structures.

CAMPAIGN RESULTS

The aim of the campaign is to introduce suitable changes in the manner in which design, execution and maintenance of concrete

structures are performed. This of course is a long term objective, and thus the effect of the campaign cannot yet be evaluated. Immediate results in the form of reports, manuals etc. can, of course, be listed, but the success of the campaign should be measured on the impact these immediate results bring about on the daily practice.

So far it seems, that the standard concrete specification will be used to a fairly large extent, and this will certainly by itself reduce the risk of future durability problems. The standard concrete specification has also made it possible to coordinate the transfer of knowledge performed by different institutions, and to direct future research efforts more effectively towards needs for revision of the specification.

It also seems that the projects on typification of repair methods will be of great importance, although a number of questions in this area still remain unsolved.

