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SURVEY OF ENVIRONMENTAL ASPECTS OF THE DANISH CONCRETE INDUSTRY

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ABSTRACT

There is no doubt that the environmental aspects will be important in the future, also in connection with cement and concrete. This is mainly because the consumption of these materials is large. The concrete industry in Denmark has considerable experience in dealing with the environmental aspects.

This article describes environmental activities in Denmark related to concrete, including the state of affairs for environmental data accessible to the public, the different environmental disciplines, experience with cleaner technologies and environmental communication systems. An overview of important, completed and ongoing projects is included. Further, future aspects of concrete and the environment are described.

Key words: Concrete, environmental data, cleaner technology, Life cycle assessment (LCA), environmental management

1. INTRODUCTION

1.1 Why deal with the environment?

There is no doubt that environmental aspects of the concrete industry will be important in the future. This is partly due to direct environmental factors (reduced resources, greenhouse effect, etc.) and partly to economic effects as a consequence of the latter (e.g. 0increased taxes, increased prices of scarce resources etc.).

The latest proposal from the Ministry of Environment and Energy, Danish Environmental Protection Agency /1/ for a future environmental policy is based on a product-effect approach. It is based on the argument that the total environmental impact only can be understood correctly - and the activities be priority-ranked correctly - if the products are considered over their whole life cycle. The goal of this approach is to increase the development, production, and sale of products with minor environmental impacts instead of existing, more environmentally damaging products.

More and more building owners are, in addition to "normal" concrete demands also specifying environmental demands for both the external environment and the working environment. This applies to the Öresund Link construction, primarily with regard to the working environment on site and noise impact on neighbours. Other building owners, for instance the Danish Road Directorate, have worked out environmental strategies which will later be specified as demands.

Recently a handbook for the consulting engineer with the purpose of assisting environmentally correct design has been prepared /2/. The handbook has been used for 15 demo projects, among these the design of a highway bridge and maintenance of a railway bridge.

1.2 The concrete industry and the environment

The environmental aspects of cement and concrete production are important, mainly because the consumption of these materials is large. This is illustrated by the fact that in Denmark approx. 1.5 tons of concrete per capita per year is produced. The CO_2 emission connected with concrete production, including the cement production, is between 0.1 and 0.2 tons per ton of concrete. This corresponds to a total of CO_2 emission of 0.6 - 1.2 mill. tons per year. Approx. 1 - 2 % of Denmark's total CO_2 emission stems from the cement and concrete production.

In the report, Viable Denmark from NOAH /3/ an environmental indicator for different industries is used. Cement is used not only as an indicator for the consumption of raw materials, such as chalk and aggregates but also as an indicator of the activities in the building industry as a whole. Also the United Nations uses cement as an indicator for environmental impacts /4/.

The concrete industry in Denmark has considerable experience in dealing with environmental aspects. The concrete industry realised at an early stage that it is a good idea to be in front with documenting the actual environmental aspects, and working on improving the environment, rather than being forced to deal with environmental aspects due to demands from authorities, customers and economic effects such as government imposed taxes etc.

Furthermore, some companies in the Danish concrete industry have recognised that reductions in production costs often go hand in hand with reductions in environmental impacts. Thus environmental aspects are not only interesting from an ideological point of view, but also from an economic point of view.

2. ENVIRONMENTAL DATA

The concrete industry, both single companies and the trade organisations, has carried out several projects primarily in co-operation with DTI Concrete Centre, where environmental data have been gathered, and are publicly accessible, /2/, /5/, /6/. The

environmental data include the consumption of energy, materials, water and output of solid waste, waste water and emissions to air.

The environmental data concern consumption of raw materials used for concrete:

Cement (white cement, low-alkali cement, high-early-strength cement and basic cement)

Aggregate (from sea, gravel pit and quarries)
Water
Flyash
Silica fume
Admixtures (air entraining agents, plasticizers, super plasticizers and retarders)
Chalk
Aluminium powder

Fly ash and silica fume are treated in such a way that the environmental data are set to zero, because the materials are residual products from another production. In table 1 an example of environmental data, i.e. the energy consumption, for selected raw materials for concrete is shown /2/, /6/. The table shows that the energy consumption for cement is many times higher than for other raw materials.

Table 1 An example of environmental data, i.e. the energy consumption (GJ/t) for selected raw materials for concrete

Cement			
High early strength	Low alkali sulfate resistant	White	Basic
6.9 GJ/t	9.7 GJ/t	9.7 GJ/t	5.8 GJ/t
Aggregate			
Sea	Quarries	Gravel pit	
0.029 GJ/t	0.068 GJ/t	0.044 GJ/t	
Chalk			
1.0 GJ/t			
Puzzolans			
Fly ash	Silica fume		
0.0 GJ/t	0.0 GJ/t		

Typically, the environmental data are gathered from a few, often only one, selected companies representing the whole industry. This means that uncertainties in the data can be large due to variations from company to company within the same industry. Of course, with regard to cement, the data represent the whole industry, because there is only one cement manufacturer in Denmark.

There are environmental data for the whole life cycle of different concrete products:

Sewer pipe
Edge beam
Pre-stressed slab element
Cellular concrete inner wall

Further, there are environmental data for the raw materials and for the production process for typical mix designs (passive, moderate and aggressive environmental class) for ready mixed concrete and for the production process for typical concrete elements (facades and load-bearing wall elements in sandwich elements, pre-stressed roof slabs and pre-stressed hollow core elements).

In an ongoing Brite-Euram project, *Cleaner Technology Solution in the Life Cycle of Concrete (TESCOP)*, carried out by DTI Concrete Centre, Aalborg Portland A/S and the Danish Concrete Element Association, and Greek, Italian, and Dutch partners, environmental data are gathered for the whole life cycle for twelve different concrete products /7/.

In /2/ the environmental data are listed together with similar data for other building materials. This makes it possible in a design situation to choose between different building materials from an environmental point of view. However, data are difficult to compare directly, as they are stated in the environmental unit per ton of the building. In each situation the actual functional unit has to be evaluated.

3. ENVIRONMENTAL DISCIPLINES

3.1 Environmental reading

An environmental reading is a mapping and a survey of a company's environmental impacts, i.e. the consumption of energy, materials and water and output of solid waste, waste water, and emissions to air. Furthermore, the amounts of produced concrete products are mapped.

After the mapping, an evaluation of the environmental data are carried out e.g. by relating the environmental data to the produced concrete amount, to requirements from laws, authorities, or customers or by relating the environmental data to economy (expenses for depositing waste, green taxes etc.).

The mapped environmental data can be inserted in a so-called mass balance model which keeps in order the input and the output for the company. A possible difference in the input and the output gives information on errors in the mapping.

The immediate result of an environmental reading is a number of environmental data which have been evaluated. The most important results of an environmental reading are followed by the activities which are initiated after the reading.

- Economic savings can be achieved by reducing relevant environmental impacts (for instance the amount of waste or consumption of energy).
- It is possible to define an environmental policy and -objectives in relation to implementation of an environmental management system.
- It is possible to prepare a green account or an environmental declaration which again can improve the company's competitiveness.
- Requirements from laws, authorities, and customers can be documented as fulfilled.

Guidance on how to carry out an environmental reading is under preparation in the project *Environmental management in the building and construction industry* /8/. In this project a software tool is also in preparation which can store, structure, and perform simple calculations as well as print environmental reports. Other software tools in relation to environmental reading are also available, but none of these are tailor-made for the concrete industry.

3.2 Environmental management

Environmental management is a systematic and planned effort in a company with the purpose of reducing environmental impacts in an economically justifiable way.

An environmental management system is a total description of how to organise, perform, report and follow up on the company's environmental efforts. An environmental management system - like a quality management system - must be periodically checked and evaluated. Unlike a quality management system where no quality improvements are required, but the level of quality shall be fixed, it is required in an environmental management system that the possibilities for improving the environmental effort shall be described and utilised in improving environmental results.

Environmental management - like quality management - means that the company determines its policy and objectives and thereafter prepares procedures and instructions which ensure that the environmental policy is followed.

Environmental management can be built up in many ways, for instance on the basis of the company's own system or after an acknowledged standard, i.e. ISO 14001 or the Eco-Management and Audit Scheme (EMAS). The objective of the international standard ISO 14001 is to promote environmental protection and to prevent pollution, balanced with economic needs. The standard aims at achieving this by setting up requirements for the companies, among others to determine its policies and fulfil laws

and requirements and to perform current improvements. It is a requirement that the environmental policy is accessible to the public.

The European model for environmental management is the EMAS-statutory instrument where a company can be registered in the European Union as a company which fulfils the statutory instrument. This means that an environmental reading shall be carried out and that the system shall be verified by external parties. Furthermore, there are requirements for making an environmental statement, and that the companies results in the environmental area are available to public.

If a company has an environmental management system according to ISO 14001, approx. 80 - 90 % of the requirements in EMAS will be fulfilled.

In the project *Environmental management in the building and construction industry*, guidance in implementing environmental management based on the ISO 14001 standard is in preparation /9/. In the same project a “get-started” guidance /10/ is also in preparation. This is a guide for the concrete companies which are not ready to implement an environmental management system based on an acknowledged standard, but wish to get started with environmental activities. The “get-started” guidance includes environmental reading, environmental policy and objectives and an environmental statement. It is possible to augment a system in accordance with ISO 14001 or EMAS.

3.3 Life cycle assessments

A life cycle assessment (LCA) is a systematic and quantitative mapping of relevant environmental impacts during the lifetime of a product. The phases in the life cycle of concrete are often defined as:

Extraction and processing of raw materials
Concrete production
Construction and re-building/extension of buildings and structures
Operation and maintenance of buildings and structures
Demolition and waste treatment/recycling

There is a broad consensus on the conducting of LCA studies. This is developed by the Society of Environmental Toxicology and Chemistry (SETAC) /11/. This code of practice is not a standard for conducting LCAs. It sets out general principles and a framework for the conduct of LCAs. On this basis, an acknowledged standard in the ISO 14000 series is in preparation.

The first step in an LCA is to perform a life cycle inventory (LCI). The result of an inventory is a list of all environmental impacts in the life cycle. If only this inventory is carried out, it is called an LCI. An LCI is the basis of every LCA. Several impact assessment methods can be applied to the same LCI data. Some are bound in scientific models (for instance calculations of greenhouse effects), and others are bound in political decisions (as for instance weighting of different environmental impacts).

Conducting LCAs results in environmental profiles or environmental scores. There is no general European impact assessment method.

The borderline between an LCA and an LCI is hard to define. Furthermore, the use of the names LCA and LCI is often not consistent. However, the work in Denmark in this area with concrete must be characterised as LCIs even though it is described as LCAs. LCA or LCI models for concrete are described in /5/ and /6/.

In the ongoing Brite-Euram project *TESCOP /7/,* where LCIs are also carried out, the assessment method is a purely political method. Political scenarios are set up with regard to the future environmental policies in the European Union and in the different partici-pating countries. With the result of the LCI and the political scenarios priorities are made in the list of results from the LCI.

Figure 1 shows an example of an LCI for the energy consumption for an edge beam /5/.

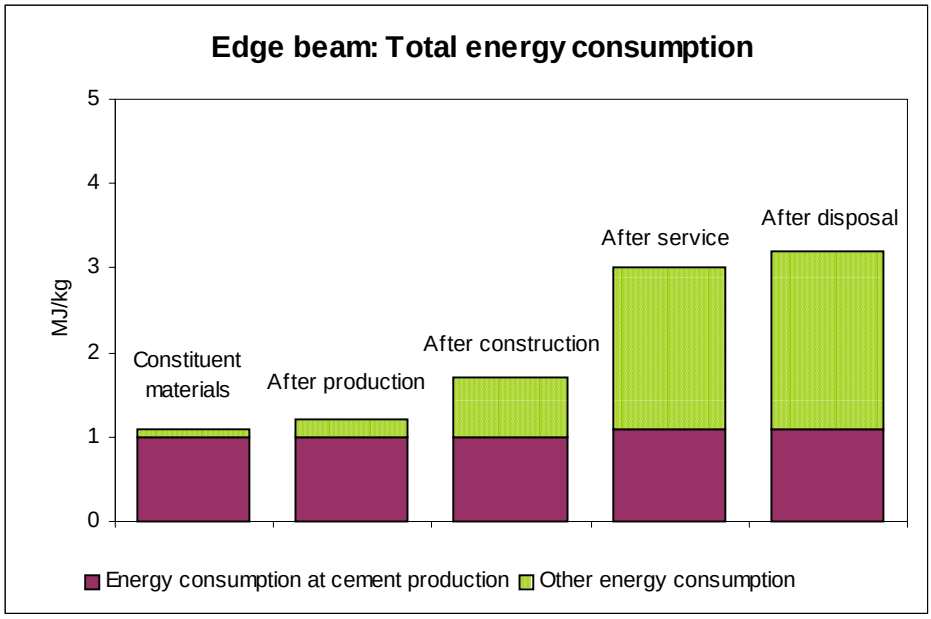

Figure 1, Total energy consumption for an edge beam

As the figure shows, the energy consumption is largest in the phases of the constituent materials and in the service phase. The production, construction, demolition, and disposal phases contribute relatively little. The energy consumption for cement production makes up more than 90% of the total energy consumption for all constituent materials and approx. 1/3 of the total life cycle energy consumption.

3.4 Environmental communication

Often, the purpose of dealing with environmental aspects is chiefly to show that the company is concerned about the environment, secondly to show specific environmental data (for instance the total CO_2 emission). This is often for competitive reasons, and can also be necessary in order to show authorities etc. that specific requirements are fulfilled.

There are several ways of communicating environmental aspects. One way is to obtain an environmental label as for instance the European Unions mark “Blomsten” (in English: The Flower) or the Nordic mark “Svanen” (in English: The Swan). Denmark has joined the “Svanen”, and at the moment a discussion is taking place between the Danish concrete industry and the Swedish Standardisation Organisation, which is responsible for the label), and the Danish Environmental Protection Agency (EPA). The discussion deals with the relevance of using a label for concrete and with the proposed requirements for concrete.

In short, the Danish concrete industry recommends that “Svanen” should not be used for concrete, because it is a simple on/off label. Instead it is recommended to use environmental declarations which give a more varied picture of a specific concrete product.

In the project on environmental management /8/, /10/ some suggestions for environmental communication are made in relation to the software programme for the environmental reading, see section 3.1. For instance it is suggested to print out a page with environmental data. This page can be handed over to the customers in the same way as the technical data of the actual concrete composition. Furthermore, in the same project there is a guide for preparing an environmental declaration.

Another very simple method of environmental communication is to obtain an ISO 14001 certificate which states that continuing environmental improvement is being made.

Finally, green accounts are an official way of communicating environmental aspects. Green accounts are obligatory on selected companies, but can also be used by the companies to communicate the environmental key parameters. The working out of the green account is regulated by law.

4. CLEANER TECHNOLOGY FOR CONCRETE

One of the purposes of performing the mentioned environmental disciplines in chapter 3 is to be able to document the environmental state of affairs. Another purpose is to obtain the basis for improving the environment, not only for ideological reasons, but also for economic reasons as described in chapter 1.

An improvement of the environment is called clean technology. This involves many aspects e.g. optimisation of the production machinery of a concrete manufacturer and optimisation of a concrete mix design. Areas where cleaner technologies are known and applied to concrete products are:

Minimisation of the water consumption of the concrete manufacturer by recycling the cleaning water.

Use of energy-saving electric bulbs and automatic switch on/off devices.

Recycling of crushed aggregate in new concrete

Use of secondary materials in cement

Use of secondary materials as fuel in cement production

Minimisation of the cement content in a concrete mix.

Change of cement type, i.e. from low-alkali cement to basic cement where the energy consumption is lower.

In the ongoing Brite-Euram project *TESCOP* the main focus is on development and implementation of cleaner technologies in the life cycle of selected concrete products. In order to determine the areas where the effect of cleaner technologies is greatest, LCIs will be carried out, and political scenarios set up, as described in section 3.3.

5. FUTURE ASPECTS

As appears from the above there is considerable knowledge about how to produce concrete with lower environmental impact, i.e. so-called “green” concrete. It is for instance well known that the type and the amount of cement in a concrete product have a significant influence on the total environmental impact.

A concrete mix can be made with lower environmental impact by changing the cement type to one of the above-mentioned new types, and by substituting part of the cement with residual products as fly ash and silica fume and other puzzolans. A cement can be made with lower environmental impact by the use of so-called mineralises such as limestone in the clinker production.

However, it is not known to a sufficient extent - either in Denmark or internationally - on what scale and with which technology this “green” concrete can be applied in practice in buildings and structures. For instance, not enough is known about the influence of “green” concrete on properties such as compressive strength, durability, fire, casting and execution, hardening and curing. Furthermore, it may be necessary to change the existing strategies for repair and maintenance.

The above-mentioned aspects will be covered in a Danish Centre Contract, Green Concrete (Grøn beton) which starts in 1998 and runs for 4 years. The partners in the Centre Contract are, apart from DTI Concrete Centre, the two technical universities in Denmark and representatives from the entire suppliers chain, i.e. cement manufacturer,

aggregate manufacturer, concrete manufacturer, contractor, consultant and a building owner.

The potential environmental benefit for society of being able to build with “green” concrete is huge. It is assumed that it is realistic to be able to develop technology which can halve the CO_2 emission connected with concrete production. With the large consumption of concrete this will potentially reduce Denmark’s total CO_2 emission by ½ - 1 %.

6. OVERVIEW OF ENVIRONMENTAL ACTIVITIES IN DENMARK RELATED TO CONCRETE

Title	Industry analysis concrete - Cleaner Technology in concrete production.
Purpose	Environmental overview over concrete. LCA for selected products.
Participants	Carl Bro Group, DTI Concrete Centre and the industry.
State of affairs	The project is completed. Reports on the project can be obtained from the Danish Environmental Protection Agency.

Title	Guidance in specification of environmental parameters.
Purpose	To set up a guide making the pre-cast concrete element producers able to collect and estimate the environmental parameters.
Participants	Polish trainee. Danish Pre-cast Concrete Federation, Betonelement a/s, DTI Concrete Centre.
State of affairs	The project is completed. The guide is available in a provisional English version.

Title	Summary of environmental impacts - Unicon factories.
Purpose	To prepare a summary of energy- and water consumption in all Unicon's ready-mix concrete factories and to analyse the causes of differences.
Participants	Polish trainee, Unicon Beton and DTI Concrete Centre.
State of affairs	The project is completed. Internal report available.

Title	Green taxes, importance to the members of Danish Pre-cast Concrete Federation.
Purpose	A survey of the economic consequences of the government's green taxes for the members of Danish Pre-cast Concrete Federation.
Participants	DTI Concrete Centre.
State of affairs	The project is completed. Internal report available.

Title	Environmental management in the building- and construction industry.
Purpose	To prepare a guide to enable the individual companies to introduce environmental management.
Participants	8 industries and trade organisations in the building and construction industry including Joint Association of Concrete Industry, DTI Productivity Centre (Project Manager), DTI. Concrete Centre is consultant.
State of affairs	The project started in autumn 1996 and lasts for two years.

Title	Environmental concrete design. Partial project. Environmental data for building materials.

Purpose	To prepare a work of reference with environmental information on the life cycle of many materials, including concrete.
Participants	Danish Building Research Institute (Project Manager), Danish Association of Consulting Engineers, DTI Concrete Centre and others.
State of affairs	The project is completed. Report can be obtained from the Centre for Building Planning Systematics, DTI Building Technology.

Title	Environmental screening of outlet components of different materials (PVC, HDPE, PP and concrete) in the life cycle.
Purpose	To explain the environmental impacts from cradle to grave of outlet components of PVC, HDPE, and concrete primarily based on existing data.
Participants	DTI Centre for Environmental Technology (Project Manager), DTI Concrete Centre, Hvorslev Consult and the plastic industry.
State of affairs	The project was started in October 1996 and completed in May 1998.

Title	Cleaner Technology Solutions in the Life Cycle of Concrete Products.
Purpose	To develop cleaner technology in the life cycle of concrete products.
Participants	Danish Pre-cast Concrete Federation, Aalborg Portland, DTI Concrete Centre (Project Manager), and other European partners.
State of affairs	The project was started at the beginning of 1997 and lasts for three years.

Title	"Swan" marking (Svanemærket) of concrete.
Purpose	To manage the concrete industry's interests in relation to the **"**Swan" mark of concrete.
Participants	Chr. F. Justesen, Aalborg Portland and Jacob Bjerre, GH Beton is participating in the group of experts, who will determine the criteria for concrete. DTI Concrete Centre is the secretary of the industry.
State of affairs	The project was started in December 1997 and completed in 1998, when the "swan" marking was excluded from concrete.

Title	Danish Concrete Society's work group on environmental use of concrete.
Purpose	To collect and organise existing knowledge about environmental use of concrete.
Participants	Moe & Brødsgaard (Chairman), DTI Concrete Centre, Cowi, Dansk Betonindustri-forening, Aalborg Portland, GH Beton, Demex, J&B.
State of affairs	The project was started in January 1998 and is expected to be completed at the end of 1998.

Title	Environmental project for light clinker concrete.
Purpose	To collect and evaluate environmental data for the life cycle of light clinker concrete and to prepare a guide to enable the producers to collect and estimate environmental data.

Participants	DTI Concrete Centre, Concrete Block Section and Light-weight Element Section, The Danish Concrete Industry Association.
State of affairs	The project was started in May 1998 and is expected to be completed at the end of 1998.

Title	Resource saving concrete structures (Green Concrete).
Purpose	To develop the necessary technology to manufacture and use green concrete.
Participants	DTI Concrete Centre (project co-ordinator) Aalborg Portland A/S (head of the steering committee) COWI Højgaard & Schultz A/S The Danish Road Directorate Unicon Concrete I/S Technical University of Denmark Aalborg University AB Sydsten
State of affairs	The project was started 1 July 1998 and will run for 4 years.

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