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RESOURCE SAVING CONCRETE STRUCTURES – THE NEED FOR NEW TECHNOLOGY

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ABSTRACT:
Old-fashioned cement is the number one source of environmental impacts related to concrete – at least as regards CO_2-emissions and energy consumption. The challenge is therefore to reduce either the cement content or to reduce the CO_2-emission and energy consumption connected with cement production

In Denmark, there is a lot of experience and knowledge about concrete with reduced environmental impacts, because all most all concrete produced contains flyash and/or micro silica. Methods for production of green concrete are also known, but at this point in time the technologic consequences are not yet known.

Therefore it is important to develop a new technology for concrete with reduced environmental impacts. The technology must include all aspects of performance.

Keywords: Kyoto, CO_2, green concrete, new technology, pozzolanes, cement, residual products.

1. CONCRETE WITH REDUCED ENVIRONMENTAL IMPACT

It is an established fact documented in a number of projects (1, 2, and 3), that old fashioned cement is the number one source to environmental impacts related to concrete – at least with regard to CO_2-emission and energy consumption. The challenge is therefore to reduce either the cement content or reduce the CO_2-emission and energy consumption during cement production. Pozzolanic materials and other waste materials can be used for both purposes.

Already today, it is possible to produce and cast very green concrete. Even a super-green concrete type without cement but with for example 300 kg fly ash instead can be produced and cast without any changes in the production equipment. But this concrete will not develop strength, and it will of course not be durable. Therefore the challenge is to develop a new technology for this type of concrete. The technology must include all aspects of performance, including:

- mechanical properties (strength, shrinkage, creep, static behaviour etc.)
- fire resistance (spalling, heat transfer etc.)
- workmanship (workability, strength development, curing etc.)

- durability (corrosion protection, frost, new deterioration mechanisms etc.)
- thermodynamical properties (input to the above)
- environmental impact (how green are the new concrete?)

These are not easy tasks and must be solved all at the same time if Owners shall be tempted to prescribe green concrete. Normally an Owner will not prescribe green concrete if the performance is lower than normal - for example a reduced service life.

The new technology shall therefore develop a concrete with all properties as normal as possible, and if any properties are not normal and shall be dealt with in a new and special way, it shall be clearly stated.

This is the objective for the Danish centre for resource saving concrete structures which is described in another paper at the XVII Symposium, Nordic Concrete Research (9).

2. DANISH STATE OF AFFAIRS

The knowledge and experience in Denmark, about how to produce concrete with lower environmental impacts can be divided into two groups, **concrete mix design** and **cement and concrete production**:

Concrete mix design:
- cement with reduced environmental impacts
- reduced cement content
- pozzolanic materials such as fly ash and micro silica
- recycling of aggregate
- recycling of water

Cement and concrete production:
- environmental management

2.1 Concrete mix design

The type and amount of cement has a major influence on the environmental properties of concrete. An example of this is shown in figure 1, where the energy consumption in MJ/kg of a concrete edge beam through all the life cycle phases is illustrated. The energy consumption of cement production make up more than 90 % of the total energy consumption of all constituent materials and approximately 1/3 of the total life cycle energy consumption.

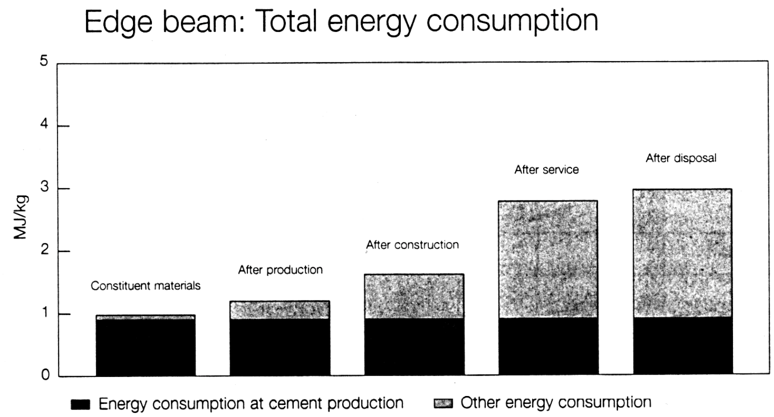

Figure 1. Edge beam: Total energy consumption through all the life cycle phases (2)

By selecting a cement type with reduced environmental impacts, and by minimising the amount of cement the concrete's environmental properties are drastically changed. This must, however, be done whilst still taking account of the technical requirements of the concrete for the type and amount of cement. Denmark's cement manufacturer, Aalborg Portland, prioritises development of cements with reduced environmental impact (3).

One method of minimising the cement content in a concrete mix is by using packing calculations to determine the optimum composition of the aggregate. A high level of aggregate packing reduces the cavities between the aggregates, and thereby the need for cement puste. This results in better concrete properties and a better environmental profile, due to a smaller amount of cement. When having experimentally determined the packing, the density, and the grain size distribution of each aggregate material, it is possible to calculate the packing of any combination of aggregates using DTI Concrete Centre's computer program (4).

Another way of minimising the cement content in concrete is to substitute parts of the cement with other pozzolanic materials. In Denmark, it is common to produce concrete with fly ash and/or micro silica. Both of these materials are residual products (from production of electricity and production of silicon, respectively) and both have a pozzolanic effect. Thus, a material with large environmental impact, i.e. the cement, is substituted with materials with reduced environmental impacts.

It is important to realise, that concrete in Denmark because of the widespread use of microsilica and flyash, is all ready very green. All most all concrete produced in Denmark today contains these products and most concrete all three powders. In short cement is used to give early strength, microsilica to give 28-days strength and flyash to give pumpability.

In table 1 typical Danish mix-design is stated for concrete for class P (Passive = indoor), M (Moderate = vertical outdoor), A (Aggressive = horizontal outdoor) and EA (Extra Aggressive = splash zones etc.).

Constituent		P	M	A	EA
Cement	C	150	200	290	300
Flyash	FA	50	60	50	30
Microsilica	MS	10	15	15	15
Water	W	135	135	140	135
W/Cc+0.5×FA+2.0×MS		0.69	0.52	0.41	0.39

Table 1, Typical Danish concrete mix-design

The restrictions on adding fly ash and microsilica laid down in the new Danish concrete materials standard (5) will be as shown in table 2.

	P	M	A	EA
Max. content of FA+MS in % of C+FA+MS	no maximum	35	25	25
Max content of MS in % of C+FA+MS	no maximum	10	10	10

Table 2, Maximum fly ash and micro silica content allowed in Denmark

In order to reduce the consumption of raw materials and to minimise the waste generated from demolished concrete structures, surplus, and production errors, crushed concrete can be reused as aggregate in Denmark.

2.2 Cement and concrete production

It is also possible to reduce a concrete type’s environmental impact by reducing the environmental impacts in cement and concrete production. The Danish cement manufacturer has many activities concerned with the reduction of environmental impact (3).

As regards concrete production, experience with reductions of primarily water consumption, energy consumption and waste production is available. Even though the contribution of concrete production to a concrete type’s environmental profile is minor, it does give a contribution, and it is important - environmentally and economically - to the single concrete producer.

In a large Danish project, “Environmental management in the building and construction industry”, a guide to environmental reading, environmental management based on the ISO 14001 standard, and a “get-started” guide are under preparation. The guide can help the concrete producers reduce environmental impacts from their production (6), (7), and (8).

3. CONCLUSION

Cement and concrete may have an important role to play in enabling the construction industry to fulfil its part of the obligation, agreed at the Kyoto conference, to reduce the total CO_2 emission.

If this challenge is not met the result could be reduction in the consumption of cement and concrete. On the other hand, if the concrete industry can develop "green concrete", the future for the most important building material - which is concrete - is green.

It is important to understand that green concrete is not a low-tech product and development of the necessary technology to use green concrete is not a task for environmental fundamentalists. Before green concrete can be introduced in the industry a comprehensive R&D programme in a number of areas must therefore be carried through.

The potential environmental benefit to society of being able to build with green concrete is huge. It is realistic to assume that the technology can be developed, which can halve the CO_2 emission related to concrete production, and with the large energy consumption of concrete and the following large emission of CO_2 this will mean a potential reduction of Denmark's total CO_2 emission by ½ -1%. Or to put it another way - concrete can deliver 3-6 % of the promised, Danish total CO_2-reduction of 21%.

4. REFERENCES

(1) Haugaard, M. and Glavind, M.: "Cleaner Technology Solutions in the Life Cycle of Concrete Products (TESCOP)". Proceedings from conference on Euro Environment, Denmark, Sep. 1998.

(2) "Industry Analysis, Concrete - Cleaner Technology in Concrete Production", Environmental Project No. 350, Ministry of Environment and Energy, Denmark, Danish Environmental Protection Agency, 1997.

(3) Damtoft, J. S.: "Use of Fly Ash and Other Waste Materials as Raw Feed and Energy Source in the Danish Cement Industry" Proceedings from CANMET/ACI International Symposium on Sustainable Development of the Cement and Concrete Industry, Canada, Oct. 1998.

(4) Glavind, M., Olsen, G. S., and Munch-Petersen, C.: "Packing calculations and concrete mix design", Nordic Concrete Research, Publication no 13, The Nordic Concrete Federation, 2/1993.

(5) DS 481 Concrete - materials (in Danish), 1999.

(6) Glavind, M. and Olsen, G. S.: "Evidence in environmental reading", Provisional Edition (in Danish), DTI Concrete Centre, 1998

(7) Olsen, G. S. and Glavind, M.: " Get-started guidance in environmental management" Provisional Edition (in Danish), DTI Concrete Centre, 1998

(8) Olsen, G. S. and Glavind, M.: " Guidance in environmental management" Provisional Edition (in Danish), DTI Concrete Centre, 1998

(9) Glavind, M., Damtoft, J.S. and Berrig, A.: Danish Centre for Green Concrete", To be published in the proceedings from the XVII Symposium on Nordic Concrete Research, August 1999.