Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 83 (1999)

Artikel: Optimisation of concrete for durability and accident resistance

Autor: Høj, Niels Peter / Rostam, Steen

DOI: https://doi.org/10.5169/seals-62820

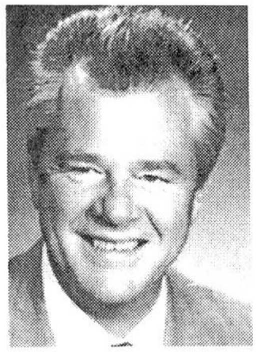
Optimisation of Concrete for Durability and Accident Resistance

Niels Peter HØJ
Project Manager
COWI
Lyngby, Denmark

Niels Peter Høj, born 1959, received his MSc from Aalborg University, Denmark, 1983. Since 1989 with COWI. His main occupations have been research, risk analyses and design. Recent activities have focused on risk assessment, particularly fires in tunnels.

Steen ROSTAM
Department Head
COWI
Lyngby, Denmark

Steen Rostam, born 1943, received his MSc from TU-Denmark 1969 and his PhD 1977. His main tasks have been durability technology and service life design of concrete structures. Rostam chairs the new ***fib*** Commission 5 "Structural Service Life Aspects".



1. Conflicting requirements

The governing requirement for the overall optimisation of structures is that the lifetime cost must be kept at a minimum. In this respect "cost" may be understood in broad terms covering both economic, environmental and safety matters, as the case may be.

To ensure fulfilment of the important requirement of durability and performance, structures must be designed to ensure safety, constructability, serviceability, appearance, maintainability, etc.

In addition, the ability to withstand relevant accidental events is essential. For concrete structures especially fire resistance may be important. This is particularly important for tunnel structures.

These two sets of requirements may in many cases be in contradiction: For example may a long service life usually be obtained with a large and dense concrete cover which, on the other hand, is susceptible to spalling damage in case of a fire. Also a possible protection of the reinforcement against corrosion by using epoxy coating may lead to problems in the case of fire, especially for bond and lap splices.

To reduce the adverse consequences in case of fire it is possible to design the structure to resist such damage and to add specific fire protection.

The main question is: Does the - usually small - likelihood of f~re and the consequence of fire damage justify large initial expenses, and do they justify compromised durability? This is the critical question to be answered.

2. Mitigating measures and fire resistance

Degradation of concrete structures can be avoided or prevented through:

- Changing of the micro environment of the concrete or restriction of transport of combustible material. It can be done by tanking, membranes and coatings which provide a protective interface between the aggressive environment and the concrete surface.
- Selecting of inert material. An example is stainless steel reinforcement which could be used in marine structures or parts exposed to de-icing chemicals. Another, but apparently less reliable solution, is coated reinforcement to provide a protective barrier against corrosive agents.
- Inhibiting the reactions or selection of fire resistant concrete compositions. Cathodic protection is one way, another is air entertainment to avoid frost attacks.

- Selection of optimal material compositions and detailing within the design. Corrosion protection can be achieved by selecting appropriate concrete covers and concrete mixes or in the detailing by minimising the exposed surfaces and adequate drainage.

A strategy for fire resistance could include:
- Coating of the concrete surface with fire protection materials.
- Using of fire-resistant concrete which can withstand a fire without spalling.
- Installation of fire-suppression systems such as sprinklers, dilution systems, gas suppression or foam suppression.
- Ventilation as an effective measure in connection with evacuation.
- Adding of plastic fibres to the concrete. The fibres will melt during the fire and thereby produce
- pores for the migration of moisture.

3. Decision support

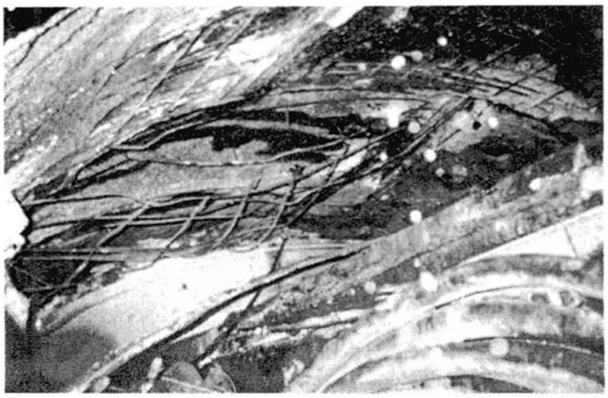
Back to the main question: Does the likelihood of fire and the consequence of fire damage justify large initial expenses, and do they justify compromised durability?

The answer is neither yes or no. It depends on the individual structural circumstances. However, today it is possible to model the circumstances and find an answer representing an overall cost optimal lifetime solution. The circumstances to be modelled may be: The type of structure, the expected lifetime, the type and aggressivity of the environment, the consequence of a durability failure, the consequences of a design fire, the possible consequence for the life of human beings, etc.

The optimisation of the concrete mix and the decision on other measures concerning these aspects, such as special provisions to enhance durability and provide fire protection, can be made based on detailed knowledge of the materials, structures, operation as well as on an analyses of the events, i.e. all in all performing a risk analyses. The framework is a decision theory. It will lead to a structural decision which is balanced in accordance with the aims, i.e. an optimised structure with respect to both durability and accident resistance.

The risk analysis must establish the probabilities of occurring deterioration mechanisms as well as fire scenarios and the combined assessment of the consequences of these actions. The probability is based on available information on deteriorating concrete structures as well as on statistical information on traffic, accidents and transport of flammable materials.

The effects and the costs etc. of all risk reducing measures must be established and used in the evaluation of the most suited set of measures.



Great Belt Tunnel after a fire during construction.

Different approaches are possible for the decision support model: Bayesian decision support, cost-benefit analyses, multi-criteria decision models, etc. The decision support models aim at the solution with the highest expected utility for the decision maker.

In practice the certain event of ageing will most often govern the decision. Therefore, concrete composition and reinforcement type and layout providing a durable concrete structure will usually be the optimal choice.