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Performance-Based Design of Structures for the Future

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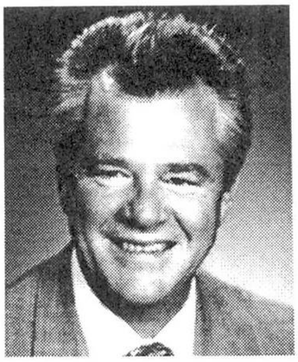


Steen Rostam, born 1943, received his MSc from TU-Denmark 1969 and his PhD 1977. His main tasks have been durability technology and service life design of concrete structures. Rostam chairs the new ***fib*** Commission 5 "Structural Service Life Aspects".

Integration of Durability and Structural Design in Performance-Based Design

The generally accepted aim of a design is "to achieve an acceptable probability that the structure being designed will perform satisfactorily during its intended life". In structural design the inherent uncertainties are taken into account by the semi-probabilistic approach using partial safety factors.

Within durability design it seems to be acceptable to use grossly over-simplified methods of verification, such as deemed-to-satisfy rules, particularly for concrete structures. The codes provide only qualitative definitions of exposure and they fail to define the design life in relation to durability. Previous approaches fail to recognise that it is the condition of the structure in its environment as a whole, that define durability and performance.

Challenge to the Designer of Concrete Structures

Concrete is the only important building material where the material properties in the finished structure are not known at the design stage and when writing the specifications. A valuable means to increase the knowledge of the expected performance and service life is to establish a base-line-study of the finally achieved properties. This could conveniently be done as a ***Birth Certificate*** and reported as part of the handing-over of the structure from the contractor to the owner. At later inspections this data can be updated as can the expected residual service life, resulting in an ever-increasing reliability of the residual service life forecast. The means are available today, and this has proven particularly valuable as a new and maybe revolutionary approach to the durability design of concrete structures.

Minimal Structures

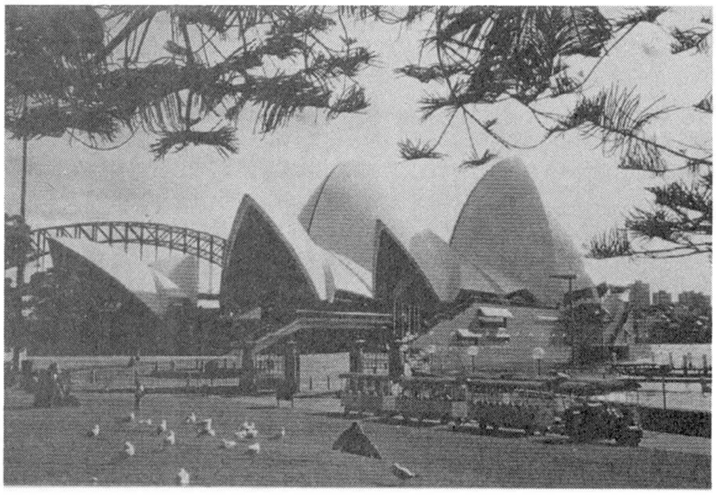
The full utilisation of the material strength throughout the structure assumes á priori that no deterioration takes place while the structure performs its long term load carrying duty under the influence of the prevailing environment. The more we engineers learn to optimise the material and structural exploitation of the strengths the greater becomes the demand also to master the ageing effects and control the deterioration mechanisms threatening the long term performance of our structures. During the 80´ies and 90´ies service life design of concrete structures has developed into a rational scientific discipline now becoming an integral part of the design of concrete structures.

Aesthetics

Concrete is a unique building material. It is used for all parts of structures. Such use requires front line technical knowledge and experience. The need to consider aesthetics in design is necessary if concrete shall not loose out to steel and other materials eager to take over the dominating role of concrete within the construction industry. In addition, it must be ensured that concrete structures grow old gracefully, thus enhancing its performance - and its reputation.

Durability Performance

Managing the durability of concrete structures will be a fundamental challenge for the engineer in the next millennium. Similar to the design concept used in structural codes, the design for durability must be developed on the basis of probabilistic analyses taking into account the variability of the environment and the structural performance. In particular, environmental factors, which affect the degradation processes, the materials and the geometrical properties, etc. may vary substantially.



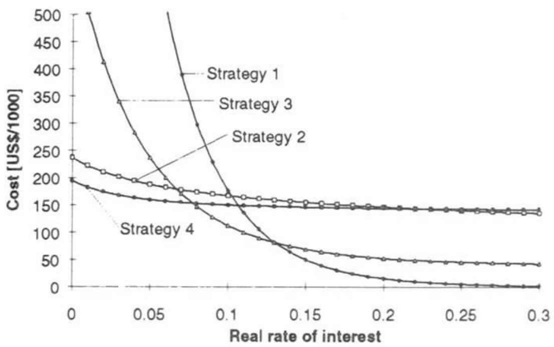
Sydney Opera House is a stimulating documentation that correct use of form and material can produce the most fascinating long lasting structure being a pleasure for the eye and for the user.

Economic Optimisation of Service Life Design

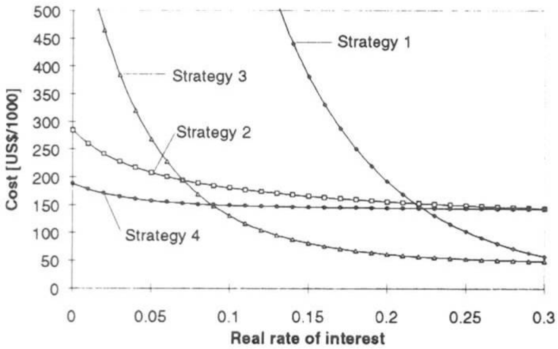
Already at the design stage the designer should consider different strategies for maintenance and repair. A fair comparison of the different strategies can be made on the basis of costs.

As an example a concrete pier exposed to chloride ingress has been analysed. The required lifetime of the structure is 50 years. A temperate climate, 10 °C, and a hot humid climate, 30 °C are checked. Four different strategies are considered. 1) A traditional structure needing extensive repair once in its lifetime. 2) A durability designed structure using high performance concrete and large covers. 3) A traditional structure prepared for cathodic protection being energised when found necessary. 4) A traditional structure but using stainless steel reinforcement in the most exposed zones, which in this case covers about half the reinforcement.

The total costs related to the four strategies are shown as functions of the real rate of interest for the temperate climate and hot humid climate, respectively.



Temperate climate.



Hot humid climate.

A rapidly growing demand for such reliability based service life designs is foreseen. This will challenge the engineering profession, and will in particular require a multi-disciplinary engineering education.

This renewal of engineering competence is needed to ensure that the future generations of engineers will be able to accommodate the rapidly growing requirements of society to provide reliable and cost optimal performance-based service life designs of structures for the future.