Durable and low-maintenance structural concrete infrastructures are long-term societal assets

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Summary

Currently there is a rapidly growing international demand for having long-term well-performing structures without premature need for maintenance and repairs. This is expressed as a demand for a specific service life of 50-75-100-120- and recently for 200 years (Messina Strait Bridge). Recent years devolpments and practical experience of servcive life design methodologies are able to provide necessary tools to satisfy the above design needs.

Keywords: durability, service life, concrete structures, design paradigm, reliability

1. Introduction

Service life performance of concrete structures pose multidisciplinary challenges on the designer and the contractor to master structural-, materials-, construction-, and maintenance properties. The growing demand for environmental awareness (sustainability) is an additional element in support of such designs. The demands for long service lives reflect also on the owner through new challenges regarding the demand that he shall define the service life design basis and corresponding acceptance criteria.

Fig. 1 Pont du Gard, build 19 B.C., road bridge section added during restoration 1743. Early segmental bridge construction now 2000 years old.

Fig. 2 The Mostar Bridge having lasted more than 400 years surviving loads and earthquakes - but brought down only by war action. The bridge has recently been rebuilt in it original shape

Fig. 3 Pantheon, Rome. The spherical dome is a 2000 years old concrete structure in full service today

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2. **Durability requirements and societal expectations**

Concrete is the most versatile and robust construction material available and has therefore obtained a dominating position in construction. Thus it becomes an economic disaster when urban dwellings, large bridges, or major marine structures deteriorate just after a few years in service. With increasing frequency such examples have been reported from the 70’s and on. The reasons are very complex but fortunately the main causes have now been identified.

During the past years clients have asked for bridge-, tunnel- and marine structures to be designed to satisfy a specified service life, this being typically 100 and 120 years, and in particular cases 200 and 300 years. With normal codes and standards usually just assuming a say 50 year design life, they are not adequate as design basis.

There is no generally agreed methodology available today on the basis of which such designs can be made and the results be verified. In fact, the present design methods do not consider the time factor on other effects than creep and shrinkage and their ULS and SLS effects.

With respect to deterioration, concrete structures have some important characteristic properties, which differ fundamentally from structures made from other structural materials. The quality of the concrete and the designed durability performance of the structure are only assumed properties at the design stage. The true quality and performance characteristics of the structural concrete are determined through the actual execution process during construction.

3. **Revised design paradigm and available tools for durability design**

The operational way of designing for durability is to define durability as a service life requirement. In this way the non-factual and rather subjective concept of "durability" is transformed into a factual requirement of the "number of years" during which the structure shall perform satisfactorily without unforeseen high costs for maintenance. In this way the time factor is introduced as a design parameter. The demand for a specific design service life is in itself not sufficient for the designer to finalise his design. The owner and Client has an additional responsibility, to provide additional information, such as:

1. Define acceptance criteria for the service life design. This means among others:
   a. Identify "the end of the Design Service Life"
   b. Define the acceptable methods of verification
   c. Define the required level of reliability of the service life design.
2. A new Design Paradigm is needed.

Recent developments and practical experience of service life design methodologies are able to provide necessary tools to satisfy the above design needs. These tools are primarily based on:

1. EU-Project "DuraCrete" (probabilistic performance based durability design of concrete structures (1998)
2. EU-Project "DARTS" (Durable and Reliable Tunnel Structures (2004))
4. Scandinavian project: NonCor (Corrosion resistant Steel Reinforcement for Concrete Structures) (2006)

A number of spectacular structures are designed along the lines outlined above in the form of:

- Bridges (PR China, Hong Kong, South Korea, Messina, Arabian Gulf)
- Tunnels (South Korea, Great Belt link, Metros)

Other prestigious buildings (Oman airport, Qatar Library, Bahrain Financial Harbour, Lusail Development Project in Qatar, etc.).