Extrapolation of Test Data in Time, Size and Risk: A Challenge for Concrete Design Codes

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Abstract

It is no secret that the lifetimes of concrete structures have been inadequate, and that structural failures are far too common, especially in the case of large structures of novel designs. This problem has two aspects: 1) randomness of loads such as those from traffic, environment and random vibrations, and 2) the uncertainty in material properties, role of corrosive agents, and failure mechanics. Significant progress has been achieved in the first, but less in the second, which is a problem of extrapolation. The second is just as important, yet has been mostly neglected by structural safety specialists. Only the second aspect is discussed in this lecture, and only in qualitative, non-mathematical, terms. A broad vision of the extrapolation problem is offered. Lapses of quality control are a different problem, not discussed here.

Keywords: Structural lifetime; extrapolation; fracture, size effect; creep; shrinkage; concrete, durability.

1 Introduction and Essence of Problem

The design of structural engineering infrastructure must be underpinned by solid experimental evidence. However, this is not the case, and is currently not feasible, for three big extrapolations—in time, in structure size and in failure probability or risk. It has long been accepted that concrete bridges should be designed for a lifespan of more than a century, but in practice many bridges need to be replaced or undergo major repairs after only a few decades. Lifetime extension is important not only economically but also for mitigating, in the long run, the huge CO_2 emissions of cement production, which are about to exceed those from all the cars and trucks in the world. Three kinds of huge extrapolations are required:

1) Much of the inadequate lifetime is due to damage from misprediction of multi-decade creep and shrinkage. Yet only 5% of the worldwide database of 4000 test series, with about 50,000 data points, assembled at Northwestern University, extends beyond 6 years and only 1% beyond 12 years. Valuable information has been obtained by inverse analysis of the recorded multi-decade creep deflections of large prestressed bridges. But the collection of such data faces legal and political obstacles, and their unambiguous interpretation is difficult.