Excessive Creep Deflections: An Awakening

Data from numerous long-span prestressed segmental box girders show alarming trend

by Zdeněk P. Bažant, Mija H. Hubler, and Qiang Yu

A previous article[1] in this magazine reported grossly excessive creep deflections of the ill-fated, record-span KB Bridge in Palau and four bridges in Japan. That article summarized the results and lessons from the analyses of those spans, while the details of creep analyses appeared elsewhere.[2] These results invited the question: Are these excessive deflections rare?

They are not, as it transpired from the search of published literature and various society or company reports undertaken at Northwestern University under the auspices of the recently formed RILEM Committee TC-MDC, Multi-Decade Creep. Despite great difficulties in obtaining information, the search has already led to the collection of deflection histories of 64 large bridge spans. Data from the initial collection of 56 span histories are shown in Fig. 1, with the deflection plotted as a function of the time from span closing. Time is plotted in the logarithmic time scale, and the diagrams are arranged in the order of decreasing 20-year relative deflection.

Where is the Limit?

The first feature that immediately strikes the eye is that after an initial period of about 1000 days since span closing, the deflections evolve systematically as a straight line in the logarithmic scale. With the exception of RILEM Model B3,[3] the observed deflections are contrary to what would be calculated using all standard engineering society recommendations, which introduce creep prediction formulas in which it is assumed that the creep compliance curves approach a finite, asymptotic bound. If this assumption were correct, the curves in Fig. 1 would level off.

Thus, Fig. 1 proves that there is no evidence for a finite asymptotic bound, and that the compliance curves of concrete must become, after about 1000 days, logarithmic curves (this fact was introduced for different reasons by Bažant in 1974[4] as part of a review of a nuclear containment design for Sargent & Lundy Engineers, Chicago, and was also proposed at that time for standard society recommendations). The logarithmic form of multi-decade deflection curve makes it possible to use a simple straight line extrapolation as a realistic prediction of the future behavior.

What is Acceptable?

The second feature to note is the deflection magnitude. The horizontal dashed lines in these diagrams indicate the deflection equal to 1/800 of the respective spans. This value is generally considered as the maximum acceptable deflection. But, according to the measured deflections or their straight-line extrapolations, the deflections of 43 spans among the 56 shown in Fig. 1 become excessive within less than 100 years, which is the normally required minimum lifetime. The deflections of 33 of the 56 spans become excessive in less than 40 years, and the deflections of 20 of the 56 spans become excessive in only 25 years. It's likely that many more excessively deflecting segmental bridges exist.

Evidently, the current method of creep design of large-span segmentally erected box girders is not sustainable. These are structures of high creep sensitivity and using a realistic creep model is important. The economic loss associated with bridge retrofit or premature closing, which may be attributed mainly to incorrect standard recommendations for creep prediction, has been truly enormous.

Action is Required

It must be emphasized that records of excessive multi-decade bridge deflections could be a gold mine of vital information for improving the standard design recommendations, provided that sufficient information on the concrete composition, environment, bridge geometry, prestressing, and construction procedures could be obtained (readers who could help are welcome to contact the authors). The existing worldwide database of the laboratory creep tests is heavily biased toward test

Fig. 1: Excessive deflections measured on 56 segmental bridge spans. Ordinates are deflection-span ratios, %; abscissas are time, days. Each horizontal dashed line corresponds to a deflection of 1/800 of the span, considered the maximum allowable. The associated vertical tick marks respectively indicate times of 40 and 10 years after span closing. Data were obtained from private communications with Yasumitsu Watanabe, Shimizu Corp., Tokyo; Jan Vítek, Metrostav, Prague; Vladimír Křístek and Lukáš Vráblík, CTU Prague; and Miloš Zich, Brno; as well as from References 6 through 12

durations of a few years and is insufficient by far for verifying and calibrating a general multi-decade creep model for standard recommendations.

In the case of multi-span bridges, Fig. 1 shows the deflections for each span separately. The deflections of adjacent spans are, of course, correlated, but only weakly so, as evidenced by their differences. The partial correlation between adjacent spans, quantifiable from the diagrams, will have to be taken into account in statistical analyses. Even though detailed information on the bridges in Fig. 1 is lacking, the deflection histories shown can nevertheless be used in joint statistical analyses of laboratory and bridge data to achieve an improvement of the multi-decade creep model. This task is attempted in a separate study.[5]

In closing, the present data document that an improved creep model and the type of analysis exemplified in References 1 and 2 are inevitable for sustainable design of structures of high creep sensitivity, if the proper lifetime is to be ensured.

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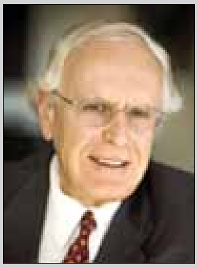

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