Nonlinear Creep Analysis of Long-span Prestressed Concrete Bridges

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Abstract

Long-span prestressed concrete (PC) bridges tend to have larger deflection than code-based estimation after several years of operation. Even though creep is usually blamed as one of the most influential time-dependent factors, most current creep models do not give sufficient attention to nonlinear creep behaviour due to higher compressive working stress. In this study, a nonlinear creep model characterized by a stress-sensitive amplification factor is proposed based on experimental data from literature. The model is embedded into the rate-type formula using several user subroutines in Abaqus. Furthermore, a computational framework is established which involves the intertwined effects of concrete creep, shrinkage, and the influence of steel strands relaxation. Finally, a long-span rigid frame box girder bridge is analysed resulting in a good estimation with the in-situ measurement in terms of the long-term deflection.

Keywords: Prestressed concrete bridge; Time-dependent behaviour; Balanced cantilever method; Nonlinear creep; Relaxation; Prestressing loss

1 Introduction

Long-span PC bridge structures often encounter the common challenge of gradual and disproportionate vertical deformation [1], particularly those built using the method of balanced cantilever construction in segments, for instance the KB bridge in Palau that the deflection of midspan reached 1.61 m and collapsed after serving 19 years [2]. Multiple potential factors contribute to the interpretation of the causes of the bridge structural degradation, such as underestimated concrete creep and shrinkage strain [3], accelerated relaxation of prestressing strands due to seasonal temperature variations [4], as well as the destructive impacts of heavy traffic loads [5]. However, creep has potentially harmful effect on the structural behaviour, durability, and operational characteristics of concrete infrastructure [6]. Notably, once the magnitude of enduring stresses exceeds the linear threshold, creep deformation exhibits a nonlinear response in relation to stress intensity, obviously exceeding the predictions generated by a linear viscoelastic model [3]. In view of this, a nonlinear creep calculation model must be established to analyze the creep effect accurately.

In the last decade, numerous researchers have addressed the evaluation of nonlinear creep behaviour of concrete. For example, Bažant et al. [7] introduced a nonlinear creep function by modifying the creep rate based on current stress level. Hamed [3] studied nonlinear creep effects in concrete under different uniaxial compressive stress with four series of specimens, and compared several nonlinear creep calculation models with the test data, it appeared that the models were conservative. Dummer et al. [8] extended the damage-plasticity model to describe the nonlinear time-dependent behaviour of concrete. To account for the nonlinear creep effect in the design and analysis of structures, using the creep coefficient or compliance function dependent on the amplification factor with the stress magnitude is a practical and effective method [9]. Some widely used models for calculating the nonlinear creep

https://doi.org/10.2749/manchester.2024.0252
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