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Time-dependent in-plane behaviour and buckling of concrete-filled steel tubular arches

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ABSTRACT

This paper presents a theoretical analysis for the time-dependent behaviour and buckling of concrete-filled steel tubular (CFST) circular arches due to shrinkage and creep of the concrete core under a sustained uniform radial load. The algebraically tractable age-adjusted effective modulus method is used to model the time-dependent behaviour of the concrete core, based on which the differential equations of equilibrium for the time-dependent analysis of CFST arches are derived and analytical solutions for the long-term displacements, stresses and internal forces of CFST arches under the sustained load are obtained. It is shown that the visco-elastic effects of creep and shrinkage of the concrete core have significant long-term effects on the in-plane structural behaviour of CFST arches. The long-term radial and axial displacements, as well as the bending moment, increase substantially with time. For a CFST arch with a low area ratio of the steel tube to the concrete core, the long-term deformations may be excessive and affect the serviceability of the CFST arch. The increases of the long-term stresses in the steel tube with time are significant, while the long-term stresses in the concrete core decrease with time and may change from compressive to tensile if the time is sufficiently long. It is demonstrated that the time-dependent change of the equilibrium configuration of the CFST arch can lead to a buckling configuration being attained in the time domain under a sustained load, which is lower than the buckling loads of the CFST arch under short-term loading. The solution for the possible prebuckling structural life for time-dependent creep buckling of deep CFST arches is derived and can be used to determine the effects of various parameters on the creep buckling of a CFST arch.

1. Introduction

This paper is concerned with the time-dependent in-plane behaviour and buckling of concrete-filled steel tubular (CFST) circular arches due to shrinkage and creep of the concrete core, which are subjected to a sustained uniform radial load q (Fig. 1). CFST arches have been widely used in engineering structures, particularly in recent bridge construction due to their light weight, high strength, convenience of construction, and aesthetic appearance. More than 400 CFST arch bridges have been constructed in recent years worldwide according to incomplete statistics [1]. The cross-section of a CFST arch consists of a steel tube with a concrete core. Because the time effects of the shrinkage and creep of the concrete core are inevitable, it is important to understand the time dependent behaviour of CFST arches due to the shrinkage and creep of the concrete core.

The shrinkage and creep of the concrete core under sustained loading may lead to an increase of the time dependent deformations of CFST arches. Hence, a CFST arch that satisfies the design requirements for the serviceability limit state in the short-term may experience excessive deformations in the long-term if the sustained loading is sufficiently high and the time is sufficiently long. In addition, CFST arches are different from lightly-reinforced concrete arches. When a concrete arch is subjected to a sustained transverse load, the concrete creep produces increases of the deformations, axial compressive force and bending moments in the arch [2]. However, the creep and shrinkage of the concrete core in a CFST arch are restrained by the steel tube. The creep and shrinkage of the concrete core tend to increase the compressive force in the steel tube, while the restrained action of steel tube tends to apply tension to the concrete and reduce the compressive force in the concrete. It is not known how the creep and shrinkage of the concrete core influence the changes and redistributions of the internal forces and stresses between the steel tube and concrete core and the resultant internal forces in the CFST arch. Furthermore, because of their high strength, CFST arches are usually quite slender

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