Low-cycle fatigue strength of steel piles

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Summary

In integral abutment bridges clamped abutment piles are in addition to a compressive normal force subjected to bending load cycles from daily and yearly temperature variations. Through experiments with full-scale specimens representing a clamped pile it is shown that a steel pipe pile loaded in bending can withstand several hundred load cycles at strain ranges greater than 6 times the yield strain with almost full load bearing capacity. By means of an example it is shown that by permitting pile strains greater than the yield strain, in contrast to most present design codes, integral abutment bridges can be erected with a span length up to 500m and a prospected service life of 120 years

Keywords: Integral abutments, low-cycle fatigue, steel piles

1. Introduction

Steel piles in integral abutments bridges may in service be severely strained due to soil restraint and yearly bridge movements which enforce displacements and rotations to the pile end that is clamped to the superstructure see Fig. 1.

The bending strains in the piles are not necessary for the bridge to soil load transfer and would of course virtually vanish in a hinged pile, but a mechanism of this kind is both more expensive and susceptible of frequent maintenance problems. A pile joint exempt of a hinge mechanism is therefore preferable in practice. A pertinent question is to what extent, if any, repeated inelastic strains might affect the load carrying capacity of a pile. Is it possible to altogether ignore such secondary effects and still retain a safe design?

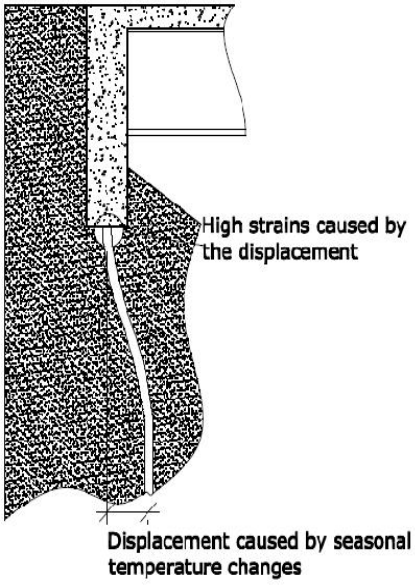

Fig. 1: An integral abutment.

Most design codes do not allow strains exceeding the yield point in the serviceability limit state. Besides a general fear of plasticization, concern for low cycle fatigue is believed to underlie this conservatism. In the ultimate limit state, however plasticization of the pile cross-section is not unconditionally out-ruled in present codes.

The ability of a pile to carry both normal force and imposed deformations at the top is supported by full scale static tests with X-shaped steel piles [1]. The aim of the new tests carried out at Lulea University of Technology, Sweden, is to demonstrate that steel pipe piles in fact are capable to withstand cyclic strains much greater than the yield strain during several hundred cycles and still safely carry the loads needed. A bridge is normally designed to be in service for 120 years in Sweden.

Some low cycle fatigue tests are described in literature. Dusicka et al. [2] tested five different structural steels with static yield strength between 100 and 485 MPa under cyclic plastic uni-axial straining in the range ±1 % to ±7% strain amplitude. Cyclic hardening was observed in all steels and the maximum cyclic stress was found to be dependent on the steel type and the strain range. They also found that steel types of similar manufacturing specifications are characterised by rather similar cyclic stress-strain curves when subjected to cyclic inelastic strain, irrespective of the monotonic yield strength and that the overall fatigue life was similar for each of the steels tested.

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