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A Two-Stage Strength Assessment Methodology for Deep Concrete Cap Beams

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1 Abstract

A significant portion of the nation's aging bridge inventory consists of bridges with deep cap beams which were not designed to carry modern traffic loads. A strength assessment of these bridges is required for accurately predicting their load and deformation capacities. This paper proposes a two-stage strength assessment methodology for deep cap beams based on a nonlinear finite element analysis. To validate the finite element modeling approach, five pier caps experimentally investigated in the literature were analyzed. Crack patterns, load-displacement response, failure modes, and governing critical members were investigated under near collapse conditions. The complete proposed methodology was employed on a case study involving five existing bridges located in Ohio and the predicted capacities were compared with the traditional sectional and strut-and-tie methods. The proposed methodology has the potential to reduce the number of bridges found overloaded using traditional methods, resulting in significant cost savings.

Keywords: bridge cap beams; deep beams; NLFEA; methodology; safety assessment.

2 Introduction

Pier cap beams are the intermediate supports between bridge spans that transfer the vertical and lateral loads from the superstructure to the foundation. Due to their large dimensions and the closely-spaced piers that they support, cap beams are often deep elements, which behave significantly different from the slender beams due to the formation of the direct strut action (i.e., a diagonal compressive stress field between the load application point and the supports). As a result, deep beams cannot be accurately analyzed using the engineering beam theory. The complexity and uniqueness of cap beams require a more advanced analysis approach.

Current advances in computational capabilities of nonlinear finite element (NLFEA) modeling have been proven to be a versatile tool for studying the nonlinear pre- and post-peak behavior of structural members [1], [2]. Recent researches have demonstrated the possibilities and advantages of the NLFEA for accurately simulating the behavior of deep beams, including the effects of shear cracking and the nonlinearity of the strain distribution [3], [4]. However, there is little guidance on how to use the result from NLFEA for determining the strength and safety of existing cap beams.

This study presents a two-stage strength assessment methodology for deep cap beams using NLFEA. The overall modeling process and strength assessment are presented through five case studies

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