Large-Scale Flexural Testing of Concrete Beams Reinforced with Conventional Steel and Titanium Alloy Bars

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Abstract

The research focuses on the use of Titanium Alloy Bars (TiABs) in concrete cap beams. TiABs offer good ductility, high strength, lightweight, superior corrosion resistance, lower overstrength, and better fatigue performance. TiABs have recently been used in several existing bridges in Oregon and Texas in the United States to increase shear and flexural capacities of concrete beams. While TiABs have been implemented in retrofitting of existing bridges in the United States, their application in new structures have not been tested and compared against conventional steel rebars. Idaho State University (ISU) has been investigating application of TiABs in new concrete structures through large-scale testing. Past research at ISU has shown that the use of titanium alloy (Ti-6Al-4V) in new bridges can reduce rebar congestion and residual drift after an earthquake by 50% while providing adequate ductility and strength compared to cast-in-place construction. The research in this paper proposes concept for an innovative cap beam reinforced with longitudinal TiABs. The cap beam integrates both structural performance and durability. Flexural and shear design procedures for the cap beam in accordance with the AASHTO LRFD Design are discussed. To investigate structural performance, a large-scale cap beam reinforced with longitudinal grade 5 titanium alloy (Ti-6Al-4V) is tested under three-point bending test protocol. The results are compared against a benchmark cast-in-place beam with normal rebars under the same testing arrangement and loading protocol.

Keywords: Innovative materials, Durability, Large-scale testing, Flexural behavior, Titanium alloy bars, Ti6Al4V, Bridges, cap beam.

1 Introduction

More than 45,000 bridges are in poor condition and were classified as “structurally deficient” (SD) in 2020 [1]. Most SD bridges need structural repair, and some might need replacement. Not all the Departments of Transportations (DOTs) have enough funds to restore each structurally deficient bridge. The estimated cost to repair or replace the 45,000 SD bridges, based on average price data from the U.S. Department of Transportation (DOT), would be $41.8 billion [1]. TiABs have played an important role in cost reduction of work force, materials as well as traffic disruption. Also, TiABs were expected to increase the life expectancy of the structures. The main reason for bridges to fail after long-term period is due to corrosion of the rebars in concrete beams. Idaho State University (ISU) conducted research on TiABs column pier in which they were able to have the better performance of bridge pier reinforced with TiABs compared to conventional normal reinforcing bars [2].