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Static and fatigue investigation of second generation steel-free bridge decks

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Abstract

This paper outlines the static and fatigue behavior of two different cast-in-place second generation steel-free bridge decks. Although cast monolithically, the first bridge deck was divided into three segments. The first segment was reinforced according to conventional design with steel reinforcement. The other two segments were both steel-free designs with internal crack control grids, one comprised of CFRP, and the other with GFRP. The hybrid CFRP/GFRP and steel strap design is called the second generation of the steel-free concrete bridge deck. The hybrid system reduces the development of longitudinal crack width and eliminates corrosion in the deck. All three segments were tested under a 25 ton and 60 ton cyclic load to investigate fatigue behavior. The second bridge deck is comprised of an internal panel and two cantilevers and incorporates a complete civionics system [Klowak C, Mufti A. Implementation of civionics in a second generation steel-free bridge deck. In: Proceedings of the 33rd annual general conference of the Canadian Society for Civil Engineering. Toronto, Ont., June 2–4, 2005]. The static test outlined in this paper is useful in the development of fatigue theory derived from the fatigue testing of the first bridge deck.
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Keywords: Steel-free; Fatigue testing; Static testing; Glass fibre reinforced polymer; Carbon reinforced polymer; Civionics

1. Introduction

The decline in North American infrastructure has never been more prevalent than it is today. In particular, the highway system and its bridges have been adversely affected by age and weathering over the past two decades. The majority of highway bridges have reinforced concrete decks supported on steel or concrete girders. Over time, the weather has taken its toll on these reinforced concrete decks. Rainwater and de-icing chemicals applied to roadway surfaces during the winter months have seeped through many concrete decks and caused corrosion of the internal reinforcing steel and deterioration of the concrete bridge decks.

This paper describes the static and fatigue behavior of two different cast-in-place second generation steel-free bridge decks. Although cast monolithically, the first bridge deck was divided into three segments (A–C). Segment A was reinforced according to conventional design with steel reinforcement. Segment B and C were reinforced internally with a CFRP crack control grid and a GFRP crack control grid, respectively, and externally with steel straps. The hybrid CFRP/GFRP and steel strap design is called a second generation steel-free concrete bridge deck. All three segments were designed with an almost equal ultimate capacity so that a direct comparison between the segments under fatigue loading conditions could be made. A performance comparison of all three segments for the first bridge deck under a 25 ton and 60 ton cyclic load is reported in this paper. The paper also outlines the details of a larger second generation steel-free bridge deck and briefly outlines some of the preliminary results from the internal panel static test. The static behavior of the bridge deck plays an important role in understanding the fatigue theory developed from the series of fatigue tests outlined in this paper.

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The deck will also be subjected to a series of fatigue tests that will help confirm fatigue theory.

2. Fatigue testing

2.1. Bridge deck details

The overall dimensions of the full-scale bridge deck were 3000 mm in width and 9000 mm in length with a deck thickness of 175 mm. It was comprised of an internal panel and two cantilevers. The spacing of the girders was 2000 mm center to center. Although cast monolithically, the slab was conceptually divided into three segments (Fig. 1). Segment A of the bridge deck slab was reinforced with steel reinforcement and was designed using the empirical design method according to the CHBDC (2000) [2]. It contained two layers of steel reinforcement with 15M bars spaced at 300 mm in both directions in each layer, providing a total reinforcement ratio of 2.08% and 0.52% in the transverse and longitudinal directions for both layers (Fig. 1).

Segment B of the bridge deck was a steel-free/CFRP hybrid design, reinforced with a CFRP crack control grid internally and externally with steel straps. The CFRP crack control grid was comprised of #10 CFRP bars spaced at 200 mm in the transverse direction and 300 mm in the longitudinal direction providing a reinforcing ratio of 0.19% and 0.13% in the transverse and longitudinal

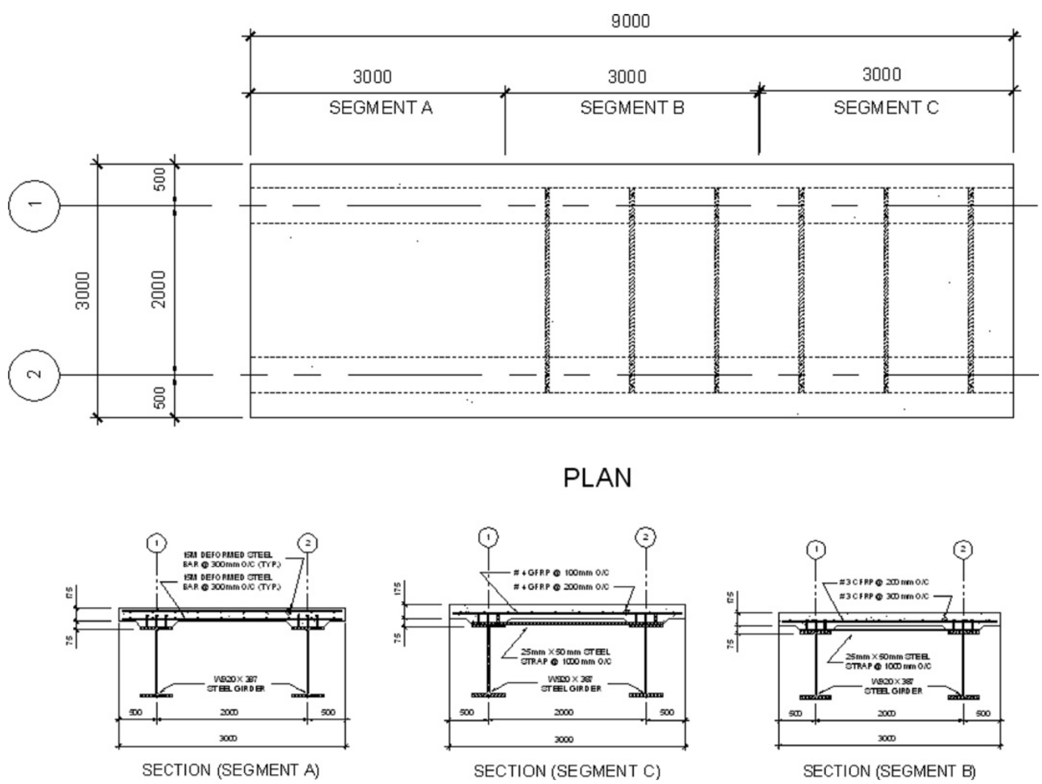

Fig. 1. Bridge deck reinforcement details.

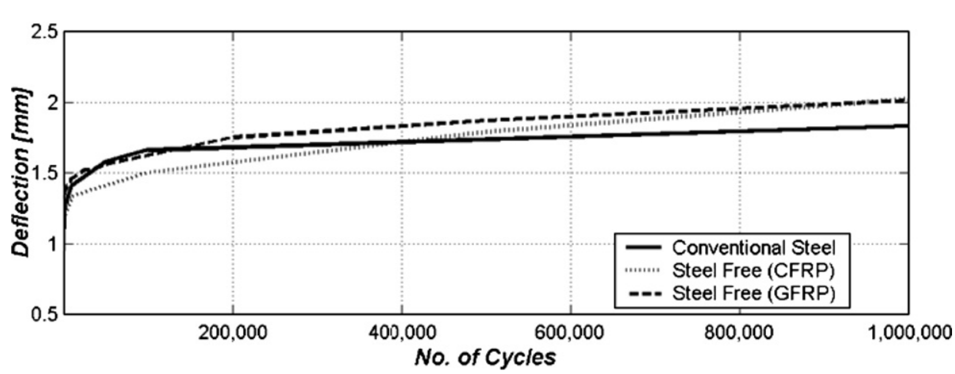

Fig. 2. Plot of deflection versus number of cycles at 25 ton.

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