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Behaviour of bridge deck cantilever overhangs subjected to a static and fatigue concentrated load

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ABSTRACT

Innovative steel-free deck slabs and deck slabs reinforced with fibre reinforced polymers (FRPs) are a solution to the problem of corrosion of internal steel reinforcement. Engineers have proposed the idea that there may be some arching-action present in bridge deck cantilever overhangs subjected to a concentrated load. An experimental research program was undertaken at the University of Manitoba to investigate this hypothesis. This paper includes the details of the experimental program required to test a full-scale innovative bridge deck with cantilevers reinforced with different top transverse reinforcing bars. The experimental results include specific information related to the static and fatigue deflection related results, strain related results, crack related results, and modes of failure. The experimental test results indicated that the static and fatigue behaviour of an unstiffened bridge deck cantilever overhang may not be completely flexural. The experimental static and fatigue destructive testing of bridge deck cantilever overhangs subjected to a concentrated load suggests that there may be the presence of arching-action. Further experimental research is required to confirm the behaviour of bridge deck cantilevers with a barrier wall subjected to a concentrated load.

1. Introduction

The aging and deterioration of highway infrastructure throughout North America is a well-known and documented problem. The majority of today's highway infrastructure network in Canada was constructed between 1950 and 1965 following World War II. At that time, bridges were typically designed for a service life of 50 years [1]. A large percentage of bridges are now at, or approaching, the end of their design service life.

Bridge decks are an important component of a bridge's superstructure. They are directly subjected to the loads induced by passing traffic. They are also the component of a bridge that is the most exposed to environment effects. One of the major contributors to the deterioration of concrete bridge decks in colder climates is the corrosion of reinforcing steel due to the use of de-icing chemicals (Fig. 1). Chloride penetration into the concrete deck accelerates the deterioration of reinforcing steel. Concrete bridges in marine environments also deteriorate at an increased rate due to exposure to salt water.

Steel-free bridge decks take advantage of the arching-action in the internal panel of bridge deck slabs to provide a system that is durable, economic, and eliminates corrosion from within the concrete [2]. Engineers have proposed the idea that there may be some arching-action present in bridge deck cantilever overhangs subjected to a concentrated load. An experimental research program was undertaken at the University of Manitoba to investigate this hypothesis.

2. Experimental program

2.1. Bridge deck details

The bridge deck was a continuous cast-in-place concrete deck measuring 9000 mm in length and 5000 mm in width. The thickness of the deck was 200 mm and it contained haunches over each of the steel girders that measured 75 mm in depth. The internal panel of the deck and the cantilevers had a span of 2500 and 1250 mm, respectively from the center-lines of each of the girders (Fig. 2). The internal panel was a second generation steel-free concept comprised of external steel straps and a bottom crack control mat of GFRP (glass fiber reinforced polymer). The two cantilevers were reinforced with three different top transverse reinforcing bars with the aim of comparing the performance between conventional steel, CFRP (carbon fiber reinforced polymer), and GFRP. The transverse negative moment reinforcement chosen for the cantilevers consisted of conventional deformed reinforcing steel, CFRP, and GFRP bars in order to provide a comparison and investigation between the three different reinforcing materials for bridge deck cantilevers. The top transverse reinforcing bars were divided into three 3000 mm sections (Fig. 3a and b). The east cantilever section of the bridge deck was reinforced with conventional black reinforcing steel consisting of 20M top transverse reinforcing bars spaced at 200 mm center-to-center. The central cantilever section of the deck was reinforced with two top transverse #13 CFRP Pultrall V-Rod [3] spaced at 200 mm center-to-center. The west section contained two top

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Fig. 1. Winter conditions and corrosion of steel reinforcement typical to many bridges in Canada.

transverse #19 GFRP V-Rod bars at a spacing of 200 mm center-to-center. The top longitudinal reinforcing bars were uniform throughout the entire length of the bridge deck and were comprised of #10 GFRP V-Rod spaced at 600 mm center-to-center.

2.2. Testing scheme

The testing scheme was comprised of six different test locations. Each cantilever section, reinforced with top transverse CFRP, steel, and GFRP was subjected to one static monotonic test to failure and one fatigue cyclic test to failure. The static tests were conducted on the north cantilever and the fatigue tests were conducted on the south cantilever (Fig. 4). The steel load plate for the static and fatigue tests conducted on the cantilever section with top transverse GFRP was located on the extreme free edge of the north and south cantilevers in the transverse direction (perpendicular to the girders) and the center-line of the load plate was a distance of 1500 mm from the west free edge of the deck (parallel to the girders). The location of the load plate for the cantilever section with top transverse steel was also located on the extreme edge of the north cantilever and 1500 mm from the east free edge of the deck. The static and fatigue test locations for the central cantilever section with top transverse CFRP were located at mid-span of the deck on the extreme edge of the north and south cantilevers, respectively.

2.3. Test set-up and instrumentation

Four concrete blocks measuring 750 mm by 750 mm by 1000 mm in depth were used to support the steel girders and the bridge deck. In order to avoid any up-lift on the adjacent girder when a cantilever was loaded, steel tie-downs were used along with high-strength Dywidag bars to tension both girders to the structural floor (Fig. 5). Four W310 × 158 steel columns were tensioned to the structural floor using high-strength Dywidag bars, and a W920 × 387 steel loading beam along with a 1000 kN capacity hydraulic actuator was used to apply load to the cantilevers.

Deflections of the cantilever and internal panel were measured using linear variable displacement transducers (LVDTs). They were measured along the center-lines of the load plate in both the transverse (perpendicular to girders) and longitudinal directions (parallel to girders). They were supported in a manner that facilitated measurement of the cantilever and the internal panel displacements relative to the deflections of the steel girders (Fig. 6).

Electronic 12 mm strain gauges were installed along the entire length of the two top transverse reinforcing bars that were located under the loading plate for all three of the cantilever sections. The top two transverse bars were located 100 mm to either side of the center-line of the loading plate in the longitudinal direction (parallel to girders) (Fig. 7). The strain gauges were located at various lengths along the top transverse bars to provide strain magnitudes along the length of the bars.

Pi gauges with a gauge length of 200 mm were used to measure static and fatigue crack widths. Two pi gauges were placed over the girder to measure crack widths at that location. Two additional pi gauges were placed along the center-line of the load plate in the longitudinal direction (parallel to girders) approximately 1000 mm from the center-line of the loading plate. A fifth pi gauge was placed on the underside of the cantilever located below the loading plate to monitor static and fatigue crack widths after observing an unexpected crack location from the first static test conducted on the central cantilever section with top transverse CFRP (Fig. 8).

3. Experimental results

The volume of test results for all six cantilever tests was too great to be presented in this paper. It is the intent of the paper to establish the general behaviour of a cantilever overhang subjected to a static monotonic load. Therefore, the experimental test

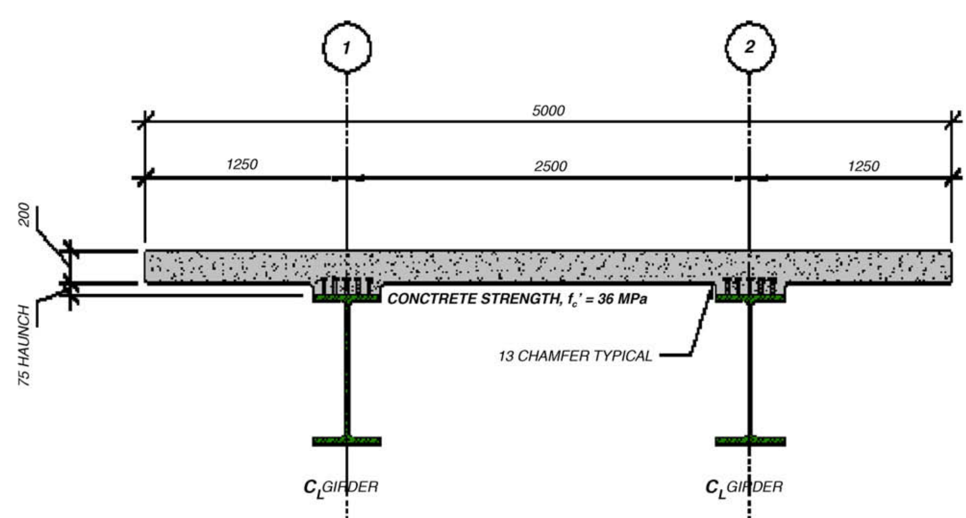

Fig. 2. Typical cross-section of bridge deck concrete details.