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Deck-pier connection detail for the simple for dead load and continuous for live load bridge system in seismic regions

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ABSTRACT

The steel bridge system referred to as Simple for Dead Load and Continuous for Live Load (SDCL) has gained popularity in non-seismic regions of the United States of America. The system provides enhanced service life and lower inspection and maintenance costs as compared to conventional steel systems. To-date, no research studies have been carried out to evaluate the behavior of the SDCL steel bridge system in high seismic regions. The SDCL concept for seismic regions requires a suitable connection between the girder and pier. The research presented in this paper investigates an integral pier SDCL steel bridge system. The structural behavior and force resistance mechanism of a proposed seismic detail was evaluated through an analytical study. An equation was developed to predict the ultimate connection capacity under seismic loading. This paper presents the results of Phase I of an ongoing, three-phase effort, that will culminate in the development of a set of details and associated design provisions to develop a version of the SDCL steel bridge system suitable for use in high seismic regions.

1. Introduction and background

A Simple for Dead Load and Continuous for Live Load (SDCL) system was developed at the University of Nebraska-Lincoln and is providing new opportunities for developing economical steel bridge systems, especially in cases for which accelerating the construction process is a priority. A summary of the research conducted at the University of Nebraska-Lincoln is provided in five AISC Engineering Journal papers [1–5]. The system has many advantages over conventional methods of constructing straight and minimally skewed steel bridges, including lower initial and life-cycle costs, easier inspection, and reduced maintenance [6–8]. The key to economic application of the system lies in selecting appropriate connection details over the interior supports to provide live load continuity. The SDCL steel bridge system appears to provide an attractive alternative for use in highly seismic regions, but research is required to fully validate the system for this use, which is the objective of the research presented in this paper.

The concept of using a simple-span girder for dead load and subsequently making the girder continuous for live load was originally developed in the 1960s for precast, pre-stressed concrete girders to prevent leakage through the deck joints in simple beam spans [9]. However, there are some major differences between the application of the system on pre-stressed concrete girder bridges versus steel girder bridges. Fig. 1 (A-conventional detail) shows a conventional two-span continuous steel bridge girder. The construction sequence consists of erecting the middle section and then connecting the two end sections using either bolted or welded field splices. This type of construction usually requires two cranes on site with associated traffic interruptions. The SDCL construction sequence independently places two simple-span girders between the abutments and pier then casts the deck slab to provide continuity for live load and superimposed dead loads only (e.g., barriers and the future wearing surface).

In the accelerated application of SDCL, the deck can be cast on the girders while offsite. The girder and deck units are placed over the supports and joined together over the pier. For example, Fig. 2 shows a photo of a bridge after placement of pre-topped units, side by side in a SDCL steel bridge.

For both pre-stressed concrete and steel girder bridges, continuity for live and superimposed dead load is typically accomplished by placing reinforcing bars over the pier and casting concrete diaphragm. In both cases, the bottom portion of the concrete diaphragms near the girders is subjected to compressive forces transferred from the adjacent girders. These compressive forces are generated by negative moments produced by traffic loads and the superimposed dead loads.

In the initial stages of the development of the SDCL for non-seismic applications, a series of preliminary finite element analyses were conducted [10], which indicated that under negative moment, the level of compressive stress being transferred from the bottom flanges to the

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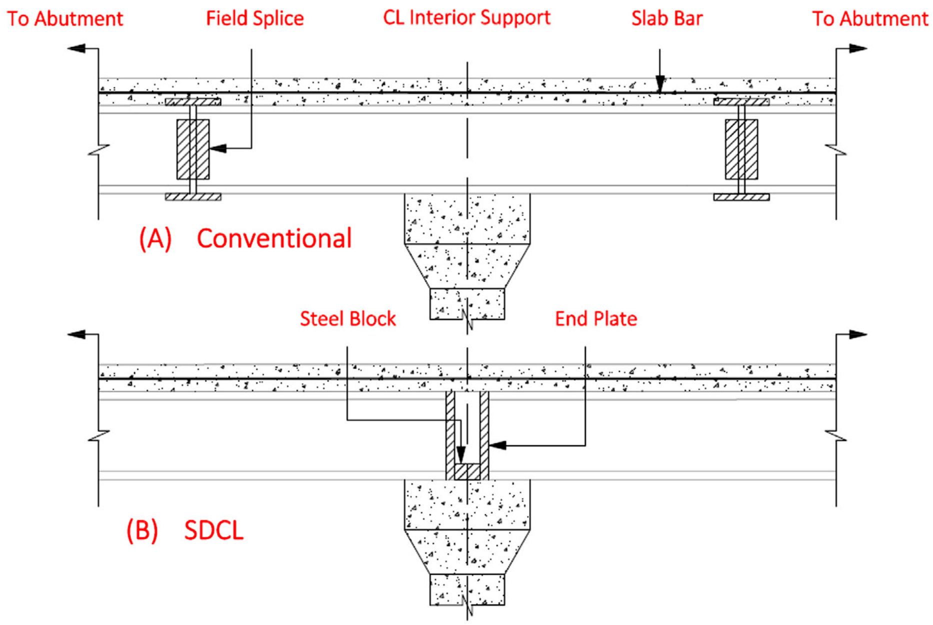

Fig. 1. Elements of (A) conventional and (B) SDCL bridge system over pier centerline.

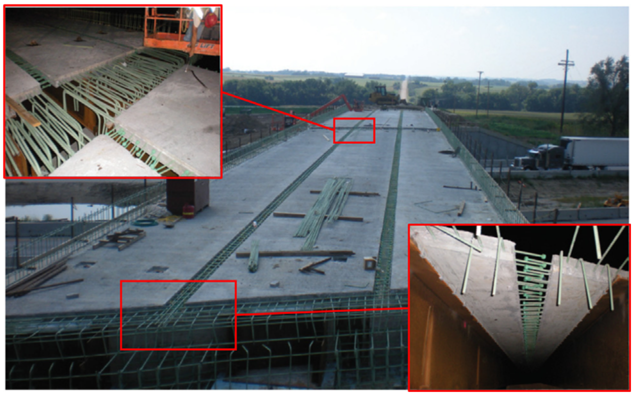

Fig. 2. Completing the placement of the pre-topped units for an SDCL system used in an Accelerated Bridge Construction (ABC) application.

concrete diaphragm were large. For instance, in a two-span bridge, with a span length of 100 ft (~30 m) and girder spacing of 10 ft (~3 m), the resulting compressive stress in the bottom of the concrete diaphragm, due to traffic loads, could exceed the compressive strength of the concrete by a factor of 4 or higher (assuming 4000-psi (~280 kg/cm^2) concrete is placed in the diaphragms). Therefore, in the case of steel bridges utilizing the SDCL concept, there was a need to develop a detail that could eliminate the possibility of crushing the concrete in the concrete diaphragm immediately adjacent to the bottom flanges of the girders. To solve this problem, three different connections at the end of the steel girders were tested in the structural lab of UNL [2]. Fig. 3 shows the details used in the three full-scale tests along with plots illustrating the moment versus deflection curve obtained from each test. As shown in Fig. 3, the test in which the bottom flanges were made continuous and end plates were added to steel the girders resulted in a larger capacity. A slight modification to the third specimen was later made, which consisted of welding steel bearing blocks to the bottom

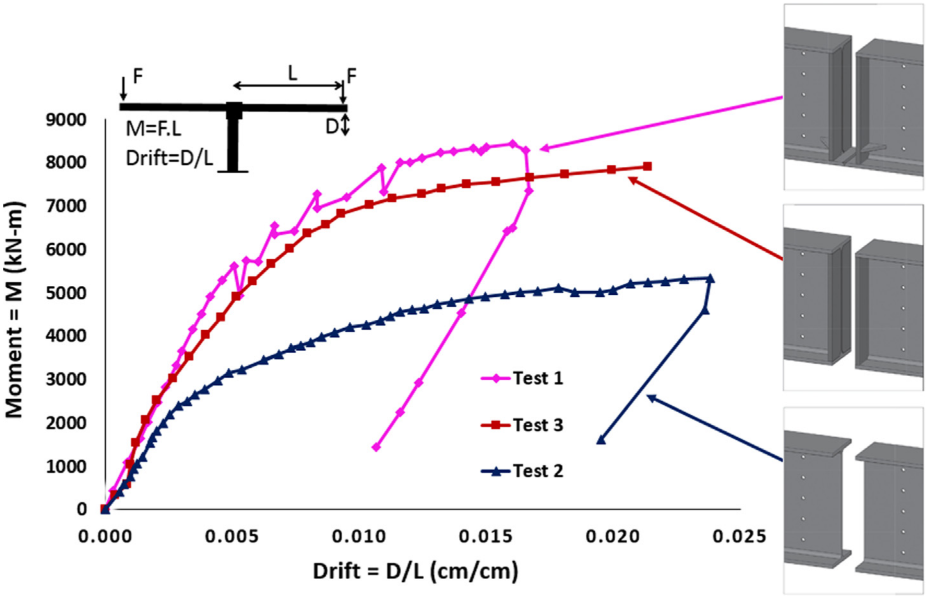

Fig. 3. Effect of end details on ultimate moment capacity.