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General Anchorage Zones of Post-Tensioned Box Girder Bridges

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***Abstract* -** Post-tensioned box girder bridges are widely used for bridge construction. The post-tensioning anchorage zone is a critical part affecting bridge performance. Very large prestressing forces are applied to the box girder, and then spread till uniform stress distribution is obtained within the box section. In order to study the performance of anchorage zones, four box girders end zones were instrumented in the field in California. These four bridges cover wide variety of anchorage zone configuration including different diaphragm width, number of girders, box girder height and openings in the end diaphragm. The field investigation led to the measurement of the actual flow of strains in the general anchorage zone. Also, experimental work was conducted at the Large Scale Structures Laboratory at University of Nevada, Reno. This experimental investigation included two single girders half-scale I-sections with rectangular solid end diaphragms. The main parameter investigated in these specimens was the diaphragm width. Loading was applied with post-tensioning tendons to represent different design levels as well as to reach the ultimate load of the anchorage zone. Increasing of diaphragm width reduces the effect of bursting forces developed in different directions of the general anchorage zones.

***Keywords*:** Anchorage Zone, Field Monitoring, Post-Tensioning, Box Girder, Finite Element Analysis.

1. Introduction

Construction issues and cracking problems occurred in anchorage zones of box girder bridges. These local problems affected the global performance of the box girder [1-2]. Current design codes do not provide a clear method for design of anchorage zones at the end diaphragm. Available design equations can be used only for rectangular sections [3-6]. In the case of a box girder, the cross section changes from a rectangular section through the diaphragm to an irregular shape at the webs of the box girder.

The anchorage zone for any prestressed member consists of two regions, local zone and general zone [3]. General anchorage zone consists of the diaphragm, web, deck and soffit adjacent to prestressing anchors; they need to have adequate reinforcement and proper concrete placement. Sufficient reinforcement must be provided to handle the spreading of forces in the general zone of the end anchorage. Adequate dimensioning and detailing of box girder end is critical for proper performance of post-tensioned bridges. In different design codes [3-6], the dimensions or detailing of these elements are not related to the design of general anchorage zone. Lack of an accurate methodology of design and detailing for anchorage zone has led to highly congested anchorage zones with construction issues and cracking problems.

2. Field Monitoring

Several research projects induced field measurement for bridges in order to study various parameters such as; aging effect [7], deflection [8] and rebars debonding [9], however none of these research projects studied the performance of general anchorage zones in box girders. Field investigation was performed for the end zone adjacent to prestressing anchors of four post-tensioned box girder bridges in order to study the performance of general anchorage zones. Different types of strain gauges were used in order to capture strains on reinforcing bars, and within the concrete elements. End diaphragms, in-span hinges diaphragms, web girders, decks and soffits were instrumented in the field using different types of strain gauges. The strain values were recorded through the whole stressing stage for prestressing tendons. The field investigation enabled the measurement of the actual flow of strains in the structure, leading to determination of force trajectories.

Recorded results from field investigation include strains in both reinforcing bars and concrete elements as well as pressure values of the prestressing jack. Using all the recorded data from different instrumentations, the adequacy of the instrumentation methodology is determined. The ratio of measured instrumentation to the total implemented ones was 88% for Bridge I, 85% for Bridges II and III, and 90 % for Bridge IV. This clarifies the adequacy of the instrumentation techniques. The obtained data is processed in order to study different parameters affecting the general anchorage zone performance. The developed strains are converted into forces in order to be capable of comparing the obtained results. The effect of diaphragm width on prestressing force spreading is illustrated for both interior and exterior girders as shown in Figure 1. The captured bursting forces were developed in the diaphragm inner face in both transverse and vertical directions, the web vertical direction and the deck transverse direction. Based on the results of both interior as well as exterior girders, the bursting forces are inversely proportional with the diaphragm width in the diaphragm, web and deck. Also, the developed forces in the interior girder are higher than those developed in the exterior girder, which highlights that the anchorage zone of interior girder is more critical.

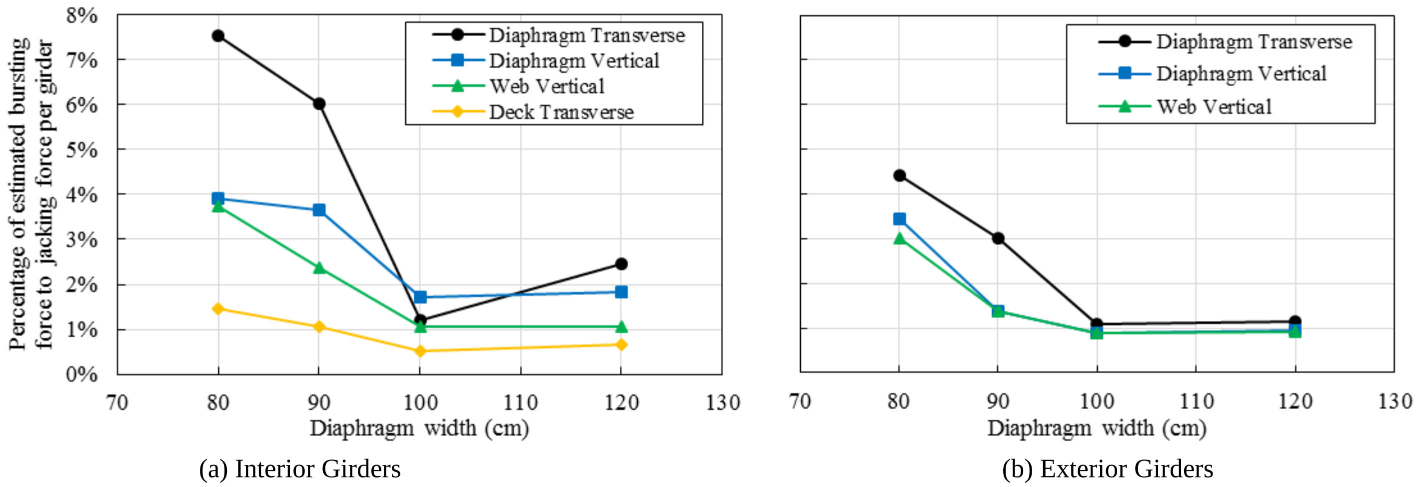

Fig. 1: Relationship between percentage of estimated bursting forces and diaphragm width for both interior and exterior girders.

3. Experimental Investigation

The experimental program was carried out to investigate the anchorage zone reinforcing of post-tensioned box girder bridges. The program incorporated two single I-section girders with different end diaphragm configurations at each end. The first specimen had diaphragm widths of 40 cm and 50 cm, however, the second specimens had diaphragm widths of 50 cm and 60 cm. The difference between the two diaphragm ends with 50 cm width was the reinforcement ratio.

3.1. Test Setup

Test setup as well as specimen preparation before testing include several working steps. General layout for experimental specimens is shown in Figure 2. Several aspects were considered during the design of experimental test setup in order to represent the prototype bridge. The effect of support reaction at each end was one of these parameters. The specimen was subjected to its own weight during testing, however this weight was not sufficient to model the prototype case. Load was applied to the experimental specimen to model the true dead weight of the prototype girder using two transverse beams, center-hole rams and vertical threaded rod connected to the lab floor as in test setup general layout. During stressing the tendon in the ducts, the specimen will camber up due to the parabolic profile for the tendons. This camber will add more force in the threaded rods, that’s why the pressure in the hydraulic system for the threaded rods was maintained constant during the whole test using pressure accumulator. The specimens were supported on two transverse beams representing the supporting abutment.

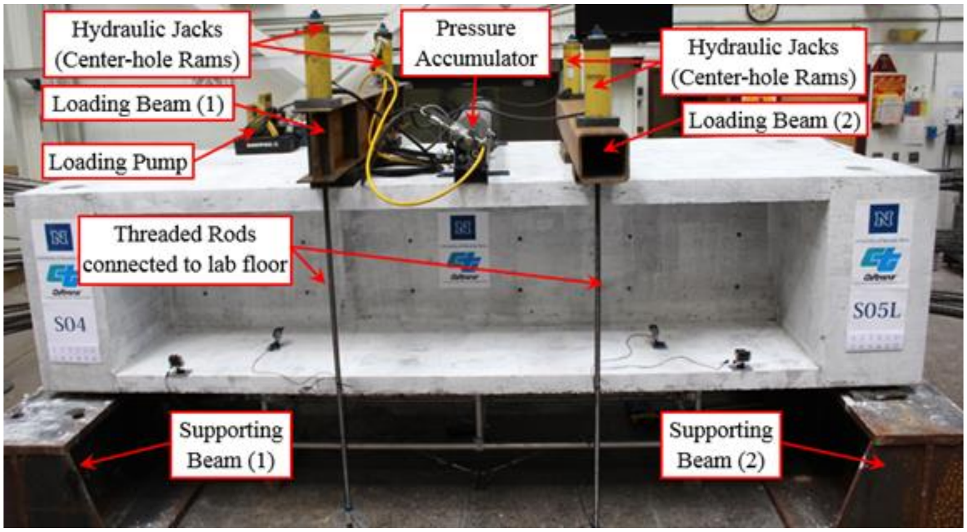

Fig. 2: Test setup general layout for experimental specimens.

3.2. Experimental Results

In order to compare the transverse strains of the diaphragm inner face, the developed strains were transformed into bursting forces to study the effect of diaphragm width. Percentage of estimated transverse bursting forces in the diaphragm inner face for experimental specimens with different diaphragm widths are presented in Figure 3. It illustrates that the transverse as well as vertical bursting forces in the diaphragm inner face were inversely proportional with diaphragm width. This coincides with the results obtained from the field investigation.

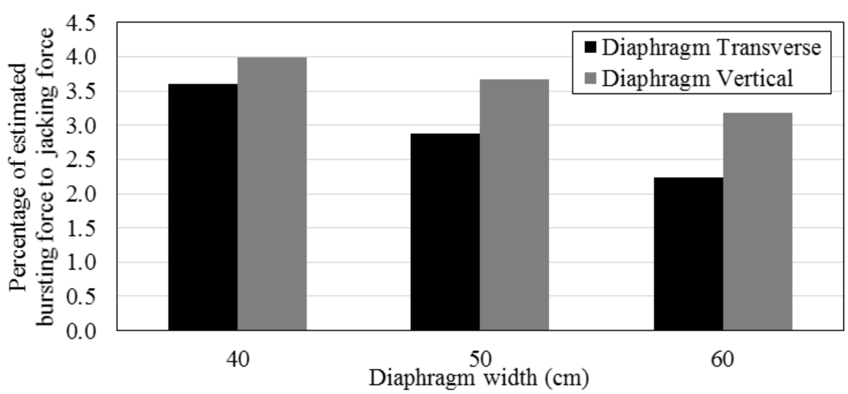

Fig. 3: Percentage of estimated bursting forces in the diaphragm inner face for experimental specimens.

4. Conclusions

Based on the field investigation results as well as experimental results, it was concluded that bursting forces in different elements are inversely proportional with the diaphragm width. This relationship highlights the role of diaphragm width in impacting the magnitude of the bursting forces caused by spreading. Also, the interior girders bursting forces are always higher than those of exterior girders, which illustrates that interior girders are more critical than exterior girders in resisting bursting forces.

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