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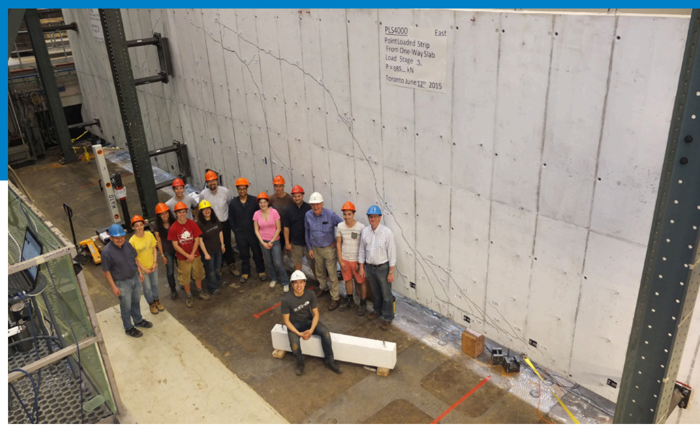

Shear in Structural Concrete

Editors:
Denis Mitchell and Abdeldjelil Belarbi

SP-328

American Concrete Institute
Always advancing

Shear in Structural Concrete

Sponsored by ACI/ASCE Committee 445

The Concrete Convention and Exposition
March 25-29, 2018
Salt Lake City, UT, USA

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Preface

This Symposium Volume reports on the latest information related to shear in structural Concrete. The volume contains 14 papers that were presented at the ACI Convention held in Salt Lake City on March 27, 2018. The symposium was sponsored by ACI/ASCE Committee 445 “Shear and Torsion”. This event honored Professor Michael P. Collins (University of Toronto) whose enormous contributions in the development of rational behavioral models for shear and torsion of structural concrete have been paramount.

The papers cover different aspects related to shear in structural concrete including: the size effect in shear for both structural concrete and reinforced masonry; developments of the Modified Compression Field Theory; aspects of shear strengthening using FRP strips; the role of experimental measurements in understanding shear behavior; accounting for shear deformations; sustained loading effects on shear in members without transverse reinforcement; crack-based assessment of shear; key aspects in the design of concrete offshore structures, behavioral models for coupling beams; finite element modeling of punching shear in slabs; and seismic design for shear.

Professor Michael P. Collins

Sincere acknowledgements are extended to all authors, speakers and reviewers as well as to ACI staff for making this symposium a success.

Editors:
Denis Mitchell (ACI 445)
Abdeldjelil Belarbi (Chair of ACI 445)

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Authors: Joost Walraven and Reza Sarkhosh

REINFORCING BRIDGE I-GIRDERS USING CFRP SHEAR STRIPS

Rico J. Massa, William D. Cook and Denis Mitchell

Synopsis:

An experimental program was carried out on full-scale precast pretensioned I-girders to study the influence on the shear response of carbon fiber reinforced polymer (CFRP) shear strips epoxied to the sides of the girders. The test program demonstrated that the CFRP shear strips were effective in increasing the shear strength of the webs and in controlling the shear crack widths. The shape of the I-girders makes it difficult to properly anchor the vertical shear strips. The curved epoxy transitions between the web and the flanges at the re-entrant corners together with the use of horizontal CFRP strips in the regions of the re-entrant corners helped to improve the anchorage of the vertical CFRP strips. The shear resistance components from the concrete, the stirrups and the CFRP shear strips, were determined experimentally and compared with analytical predictions. The results from this experimental study are compared with the test results from other researchers. The design approach of the 2014 Canadian Highway Bridge Design Code provides conservative estimates of the shear strength of the webs.

Keywords: shear; shear strengthening; CFRP; crack widths; prestressed concrete; bridge girders

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INTRODUCTION

This paper presents the results from an experimental program to investigate the effects of using Carbon Fiber Reinforced Polymer (CFRP) vertical strips epoxied to the webs of precast pretensioned I-girders. Vertical shear strips anchored by horizontal CFRP strips have been used to provide shear strengthening of 100 I-girders in the Champlain Bridge (see Fig. 1). The objective of this research project was to study the beneficial effects of using vertical and horizontal CFRP strips to enhance the performance of bridge I-girders in shear, particularly in light of some experimental results that indicated that I-girders experienced little shear strength gain when CFRP shear strips were added (Belarbi *et al.* (2011) and Kim *et al.* (2012)).

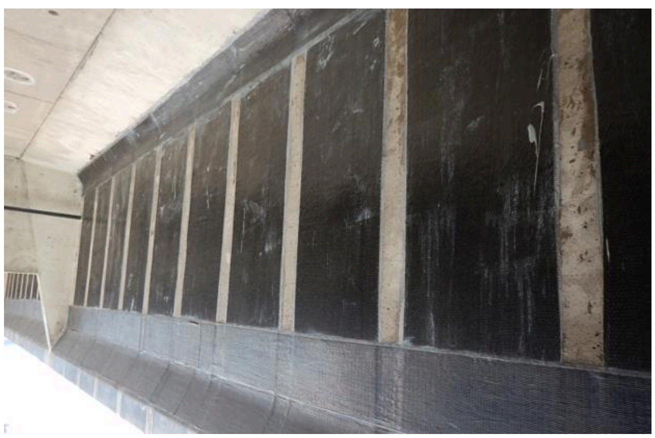

Figure 1 — Application of CFRP vertical shear strips and horizontal anchor strips on I-girders of the Champlain Bridge in Montreal (Courtesy of the Jacques Cartier and Champlain Bridges Inc.)

PREVIOUS RESEARCH

Very few experiments on precast prestressed concrete I-girders strengthened with CFRP shear strips have been reported in the literature (see Fig. 2). Kang and Ary (2012) investigated the influence of CFRP strips on the response of relatively small precast pretensioned I-girders that did not have a deck slab. The girders had a total depth of 20 in. (508 mm) and had 4 in. (102 mm) thick webs, with a clear web height of 10 in. (254 mm). The presence of CFRP shear strips on Girders IB-10 and IB-5 resulted in strength increases compared the control beam without CFRP of 1.5% and 38.9% for the case of CFRP strip spacings of 10 in. (254 mm) and 5 in. (127 mm), respectively. The shear strengthening consisted of CFRP vertical strips only with no additional anchorage details.

Belarbi *et al.* (2011) tested four full-scale precast pretensioned I-girders that experienced diagonal tension failures. These girders had an 8 in. (203 mm) thick deck slab and had an overall depth of 47 in. (1194 mm). The web thickness was 6 in. (152 mm), with a clear web height of 20 in. (508 mm). A number of different CFRP details were investigated and the shear strengths were compared to the shear capacity of the control girder T3-18-Control that did not have CFRP. The shear capacity of the control girder was 252 kips (1121 kN). Girder T3-18-S90-NA, reinforced