Report

Precast/Prestressed Concrete Institute

Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders

CB-02-16-E

First Edition

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Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders

Publication CB-02-16-E

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PCI Publication CB-02-16-E

First Edition 2016

ISBN 978-0-9968021-3-0

This document has been prepared and reviewed through an extensive Precast/Prestressed Concrete Institute (PCI) Committee process to present state-of-the-art information on the lateral stability of precast, prestressed concrete bridge girders. Substantial effort has been made to ensure that all collected data and information included in this report are accurate. PCI, the committee members, the authors, and the quoted agencies cannot accept responsibility for any errors or oversights in this report, the use of this material, or in the preparation of any design and engineering plans. This document is intended for reference by professional personnel who are competent to evaluate the significance and limitations of its contents and who are able to accept responsibility for the application of the material it contains. Actual conditions on any project must be given special consideration and more specific evaluation and engineering judgment may be required that are beyond the intended scope of this work. The contents do not necessarily reflect the official views or policies of the agencies mentioned, and do not constitute a standard or policy for design or construction.

Printed in the United States of America

FOREWORD

Precast, prestressed concrete has been used extensively in the nation's highway bridges beginning in 1949. The rigorous construction of the interstate highway system in the 1950s, and the subsequent development of higher performance materials and methods, resulted in the recognition that precast, prestressed concrete is the most durable, cost-effective bridge construction solution for the span ranges in which it is applicable.

Girders are manufactured in sophisticated plants on permanent casting beds in strong, accurate steel forms. The plants use high-strength, high-performance concrete that assures rapid fabrication cycles and excellent long-term performance. Pretensioning is used to prestress the girders.

PCI is acknowledged to be the body of knowledge of the precast and precast, prestressed concrete industry. Since 1954, PCI has researched, refined, and published the technology of this industry. PCI developed comprehensive guidelines and standards for drafting, design, production, quality control, and installation of precast concrete. It administers the industry's first and most comprehensive family of certification programs for personnel, production, and erection of precast concrete—all of which are predicated on a continuous process of quality improvement.

Due to the trend toward using longer girders, in 2007, the PCI Bridge Committee recognized the need to develop and disseminate information about the lateral stability of prestressed concrete girders during all stages of construction, and to provide recommendations to practitioners throughout the industry including designers, manufacturers, and the owner agencies. In that year, they established the Girder Stability Subcommittee and accepted membership of a select group of industry stakeholders. This report is the result of its work.

This recommended practice adds to the body of knowledge. It provides for the evaluation and analysis of laterally-sensitive bridge girders. PCI will continue to develop this technology to provide guidance to bridge design and construction practitioners.

Suggestions, questions, and comments concerning this document are welcome. Please contact Managing Director Transportation Systems at PCI; telephone 312-786-0300, or send your email to PCIBridgeManual@pci.org.

DEVELOPMENT AND REVIEW

Throughout the development of this document, strict adherence to the PCI policies has been followed, including a series of comprehensive reviews. The outline and each draft were reviewed by the PCI Girder Stability Subcommittee and its consulting members who replied with written comments. These comments were generally discussed at the semi-annual meetings of the subcommittee and electronically at intermediate intervals. The subcommittee balloted the final draft and all written comments were accommodated. The PCI Committee on Bridges reviewed and balloted the final draft. The document was submitted to the PCI Technical Activities Council (TAC) for assurance that it meets the Institute's standards for technical content and quality guidelines for presentation. Primary and secondary comments resulting from these ballots were resolved by the subcommittee and subsequently approved by the reviewing committees.

ACKNOWLEDGEMENTS

During the development of this document, governmental agencies and universities including the Florida Department of Transportation, The Texas Department of Transportation, the (Virginia Tech), have undertaken research to resolve many of the outstanding issues related to girder stability. Their hard work and determination to resolve these issues and improve safety during construction is recognized and greatly appreciated. Much of their research has been incorporated into this document.

Many others in addition to the subcommittee engaged in discussions at the meetings and read one or more of the progression of drafts. PCI wishes to thank all of these professionals for their time and expertise. Many of those who participated in the writing and review of this document are acknowledged below.

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Each main section in the text is identified with a decimal numbering system similar to the system used for various AASHTO Specifications and the PCI Bridge Design Manual. This is the system used to organize this page you are reading. The hierarchy of the system is also apparent by the type size and font used in the titles of the sections.

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All figures and tables are numbered to the section where they first appear. Example: **Figure 3.2-1** is found in Section 3.2 and **Figure 3.2-2** is the second figure to appear in the same section. Figures and tables referenced in the text are in **bold type**.

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Your suggestions and comments concerning this document will be greatly appreciated. Call, write or e-mail to “Bridge Engineer” at the location and telephone number on the inside cover page, or email PCIBridgeManual@pci.org.

UI 3.2 Our Suggestion
We strongly urge the designer, in the early stages of a project, to contact one or more PCI-Certified precast concrete manufacturers. The manufacturer can advise about local experience and capability. The producer can often help with suggested solutions and cost estimates. They can provide specific design information about special local, state or regional precast sections. A current list of PCI-Certified producers is readily available on the PCI website at www.pci.org.

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LIST OF FIGURES

NOTATION

CF = centrifugal force
E_c = modulus of elasticity of the girder
e_h = lateral eccentricity of the horizontal component of the tension force from the roll axis to the section under consideration
e_i = initial lateral eccentricity of the center of mass of the girder with respect to the roll axis or center
e_{wind} = eccentricity of the girder weight for girder subjected to WS
F_h = horizontal component of lifting force due to sloped slings
FS = factor of safety
FS' = factor of safety for the cracked girder section at rollover
f_c = compressive strength of concrete during a specific stability event
$f_c^{'}$ = specified compressive strength of concrete
$f_{ci}^{'}$ = specified compressive strength of concrete at time of initial prestressing
h_{wind} = vertical distance from roll center to mid-depth of girder
h_r = height of roll center above the roadway
h_{CE} = vertical distance from roll center to center of mass of girder
I_y = moment of inertia of the girder about the y-axis
K_1 = modulus of elasticity correction factor for local aggregate
K_θ = rotational constant of the spring support
$K_{\theta 1}$ = rotational constant of the single spring support
L = span length between roll centers
M_a = acting moment
M_r = resisting moment
$M_{y.crack}$ = lateral moment applied to the girder that causes tensile cracking in the most critical flange
M_z = gravity moment of the girder
P_{cr} = critical buckling load
P_h = horizontal component of the tension force in an inclined cable
W = weight of the girder
w_c = unit weight of plain concrete
WS = wind force on girder or structure
y_{cm} = height of the lift point roll center above the center of mass of the girder along centerline of girder
y_{lift} = height of the lift point roll center above the top of girder
y_r = distance from the roll axis/center to the center of mass of the girder
z = lateral deflection of the girder under self-weight
z_o = lateral eccentricity of the center of mass of the deflected shape of the girder subjected to W applied as a lateral load
z_{wind} = lateral deflection of the girder subjected to WS
z_{CE} = lateral deflection of the girder subjected to CE
z_{max} = distance from the center of bunking surface to the centerline of the dual tires on the truck
α = superelevation of the roadway supporting the vehicle
α = slope of a single spring support
ϕ = angle between sloped lift sling and horizontal
θ = rotation angle of the girder from vertical
θ_{eq} = rotation angle at equilibrium
θ_{max} = rotation angle of the girder from vertical that causes girder cracking
θ'_{max} = critical rotation angle at rollover

Note: This notation applies to Sections 1 through 5. A separate notation for Section 6 and App. B is in Section 6.

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1.0 INTRODUCTION

Precast, prestressed concrete girders became an important bridge superstructure component in the 1950s. Concrete strengths have progressively increased over the subsequent decades resulting in significantly longer spans. With longer spans came the challenge to produce long slender girder sections that are laterally stable during production, transportation, erection, and during construction of the bridge deck. A history of lateral stability failures indicated the need for a reliable analysis to check the stability of these girders for all phases of their transition from the casting bed to incorporation into the bridge superstructure. This document provides guidelines for the analysis of stability of prestressed concrete girders from "bed to bridge" along with the fundamental principles behind the analysis methods.

The issues relating to the lateral stability of precast, prestressed concrete girders are addressed in subsequent sections of this document:

Current Practice: A survey was developed and sent to all state bridge engineers and other industry professionals to determine the processes in place to ensure stability of prestressed concrete girders from bed-to-bridge. Some of the questions presented to these agencies, addressed who had professional responsibilities for ensuring stability along with their experiences with girder failures and rejection of girders due to excessive lateral deflections.

Girder Stability Basics: The basic theory for lateral stability of prestressed girders is presented in this report. The theory builds on the widely accepted analysis methods developed and presented by Robert F. Mast (1989, 1993), adding additional criteria that should be evaluated.

Criteria: This section discusses the various criteria to be considered for design.

Lateral Stability Considerations from Bed to Bridge: This section presents a discussion of the various conditions to be considered for the following stages in the life of a prestressed girder:

- Transfer of prestress force
- Lifting the girder from the casting bed
- Transportation to the yard storage area
- Support conditions in the yard storage area
- Transportation to the project site
- Erection at the project site
- Bracing requirements during the construction or reconstruction of the deck

Example Calculations: A series of calculations are provided to illustrate the lateral stability analysis methods. All of the conditions stated above are investigated in the examples. A number of variations are also illustrated such as the effects of wind or no wind, various wind speeds, and two roadway cross slopes.