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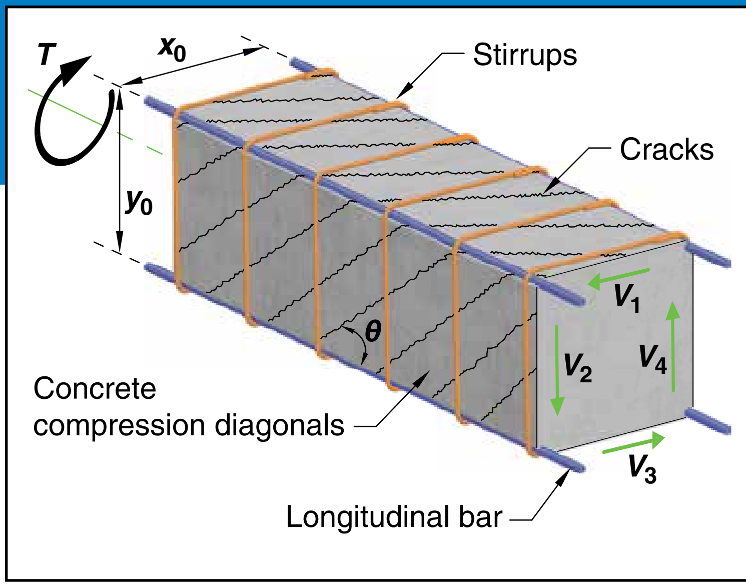

Examples for The Design of Reinforced and Prestressed Concrete Members Under Torsion

SP-344

Editors:
Eva Lantsoght, Gary Greene, and Abdeldjelil Belarbi

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PREFACE

Examples for the Design of Reinforced and Prestressed Concrete Members Under Torsion

The design and analysis of structural concrete elements is a topic of practical interest. While sometimes the effect of torsion is only addressed based on simple examples, practicing engineers are faced with the need to include the effects of torsion in their designs of a variety of structures and load arrangements.

This Special Publication (SP) contains papers about the design of reinforced and prestressed concrete elements for torsion. The focus of the SP is on practical design examples according to different concrete bridge and building codes. In addition to the design examples, papers dealing with the current state of the art on torsion in structural concrete, as well as recent advances in the analysis and design of concrete elements failing in torsion, are added.

The objectives of this SP are to provide practicing engineers with the tools necessary to better understand and design concrete elements for torsion. The need for this SP arose after the development of the State-of-the-Art Report on Torsion of Joint ACI-ASCE Committee 445 "Shear and Torsion" and Subcommittee 445-E "Torsion". Usually, the attention that is paid to torsion in engineering education is limited to simplified textbook examples. The examples in this SP show applications in bridges and buildings, where the torsion design is combined with the design for flexure and shear. Additionally, the examples in this SP give insight on the different outcomes when using different bridge and building codes. Finally, the papers that include theoretical considerations give practicing engineers a deeper understanding and background on torsion in structural concrete.

The views from an international group of authors are included in this SP, subsequently representing a variety of building and bridge codes the engineer may encounter in practice. In particular, authors from the United States, Canada, Ecuador, the Netherlands, Italy, Greece, and the Czech Republic contributed to the papers in this SP. Views from academia and the industry are included.

To exchange experience in the design of torsion-critical structures as well as new research insights on torsion, Joint ACI-ASCE Committee 445 and Subcommittee 445-E organized two sessions titled "Examples for the Design of Reinforced and Prestressed Concrete Members under Torsion" at the ACI Fall Convention 2020. This SP contains several technical papers from experts who presented their work at these sessions, in addition to papers submitted for publication only.

In summary, this SP addresses numerous practical examples of structural elements under torsion in bridges and buildings, as well as insights from recent research applied to practical cases of elements under torsion. The co-editors of this SP are grateful for the contributions of the authors and sincerely value the time and effort they invested in preparing the papers in this volume, as well as the contributions of the reviewers of the manuscripts.

Eva Lantsoght, Gary Greene, and Abdeldjelil Belarbi
Co-editors

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OVERVIEW OF TORSION DESIGN METHODS

Camilo Granda Valencia and Eva Lantsoght

Synopsis: Large torsional moments, which need to be considered in a design, can result among others, in structures with an asymmetric layout or loading. To find the required longitudinal and transverse reinforcement to resist these torsional moments, the link between the three-dimensional action of the torsional moment and sectional analysis methods is necessary. This paper reviews the existing methods and code provisions for torsion. First, an overview of the principles of torsion from the mechanics perspective is given. Then, a survey of the available mechanical models for torsion is presented. Finally, the code provisions for torsion of ACI 318-19, CSA-A23.3-04, AASHTO-LRFD-17, EN 1992-1-1:2004, and the fib Model Code 2010 are summarized. Additionally, current research topics on torsion in structural concrete are summarized. It is expected that with this paper, engineers will have a useful overview and background knowledge for the design and assessment of torsion-critical elements.

Keywords: codes, concrete, reinforcement, shear, torsion

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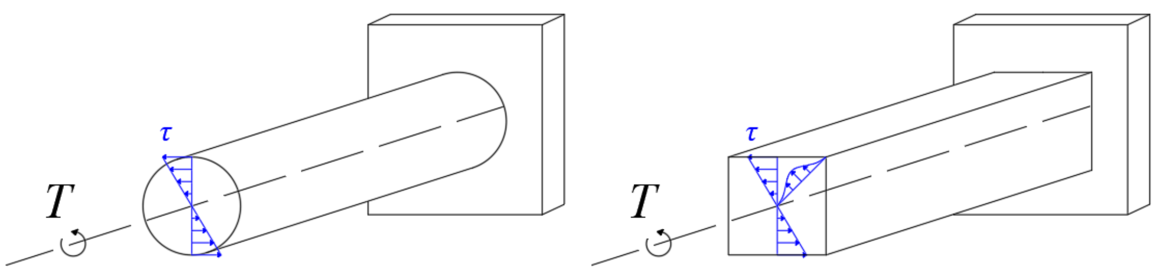
INTRODUCTION

In general, concrete structures are subjected to four principal actions: axial force, shear, bending moment, and torsion. Engineers and researchers focused on the understanding of the first three phenomena in concrete structures because these usually control the design of a member, i.e. they control the resulting reinforcement layout. For example, beams are typically designed for sectional moment and shear. Columns work as flexion-compression elements, around both axes of the cross-section. Nevertheless, torsion is a special topic. It was left apart because generally its influence on the resulting design is limited. For this reason, building codes accounted for torsion's small influence in the safety factors[1]. Throughout the 1960s, extensive research on torsion was made. As a result, the first design recommendations for torsion made by the American Concrete Institute (ACI) were formulated in 1969[2]. These recommendations led to the inclusion of provisions for torsion in the 1971 edition of the ACI Building Code, ACI 318-71[3]. The research carried out over the past decades led to a better understanding of the behavior of concrete members subjected to a torsional moment. The Space Truss Analogy, the Skew-Bending Theory, and other theories provided mechanical models to predict the behavior of concrete structures under torsion after cracking.

Torsion can be defined as the moment that twists an element around its axis. This torsional moment causes shearing stresses at each point of the cross-section of an element. These stresses change according to the proximity to the member's axis[4]. In circular cross-sections, the stress caused by a torsional moment is zero at the neutral axis and reaches the maximum value on the outermost fiber, see Figure 1(a). For rectangular cross-sections, the shear stress is also zero at the neutral axis and at the corners. It increases towards its maximum value at the surface of the longest side, see Figure 1(b).



(a) (b)

Figure 1—Shear stresses (τ) due an applied torsional moment (T) on a circular (a) and rectangular solid (b) element

Torsion can be a result of primary or secondary actions. The primary action occurs when the member can only support the action of an external load by generating a torsional moment. This is also called equilibrium torsion and is common in statically determinate structures. Equilibrium torsion is important for the stability of the structure. This occurs, for example, when a load acts on a fixed-end beam, but it is applied eccentric with respect to the z-axis, like in Figure 2. As a result, a torsional moment is generated around this axis.

Torsion can also be found as a result of secondary actions in statically indeterminate structures. This happens because the structure needs to satisfy compatibility requirements. In this case a twist is required to maintain the compatibility, not a torsional moment[5]. Spandrel continuous beams supporting other secondary beams or slabs are often subjected to this phenomenon, as shown in Figure 3.