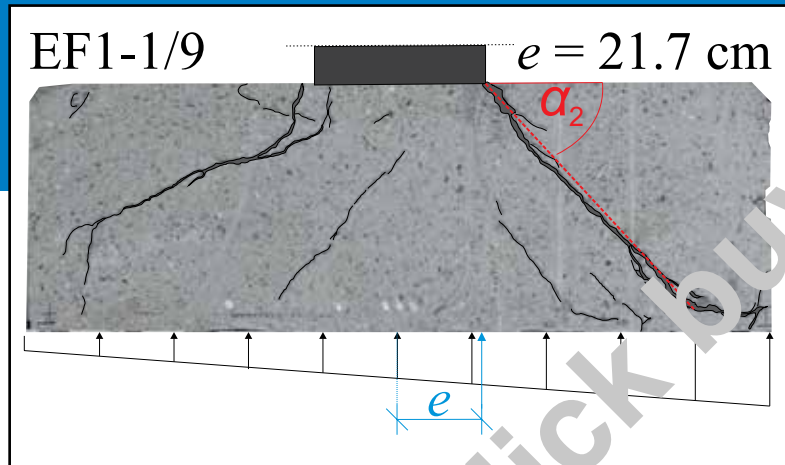


An ACI Technical Publication

SYMPOSIUM VOLUME



Punching Shear of Concrete Slabs: Insights from New Materials, Tests, and Analysis Methods

Editors:

Aikaterini Genikomsou, Trevor Hrynyk,
and Eva Lantsoght



American Concrete Institute
Always advancing

Currently in preview, click buy full version

Punching Shear of Concrete Slabs: Insights from New Materials, Tests, and Analysis Methods

Sponsored by
ACI Committees 421, 445, and 445C

ACI Concrete Convention
April 2-6, 2023
San Francisco, CA

Editors:
Aikaterini Genikomsou,
Trevor Hrynyk, and
Eva Lantsoght



American Concrete Institute
Always advancing

SP-357

First printing, April 2023

Discussion is welcomed for all materials published in this issue and will appear ten months from this journal's date if the discussion is received within four months of the paper's print publication. Discussion of material received after specified dates will be considered individually for publication or private response. ACI Standards published in ACI Journals for public comment have discussion due dates printed with the Standard.

The Institute is not responsible for the statements or opinions expressed in its publications. Institute publications are not able to, nor intended to, supplant individual training, responsibility, or judgment of the user, or the supplier, of the information presented.

The papers in this volume have been reviewed under Institute publication procedures by individuals expert in the subject areas of the papers.

Copyright © 2023
AMERICAN CONCRETE INSTITUTE
38800 Country Club Dr.
Farmington Hills, Michigan 48331

All rights reserved, including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by any electronic or mechanical device, printed or written or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

Printed in the United States of America

Editorial production: Gail L. Tatum

ISBN-13: 978-1-64195-212-5

Punching Shear of Concrete Slabs: Insights from New Materials, Tests, and Analysis Methods

The design, analysis, and performance of structural concrete slabs under punching shear loading conditions are topics that have been studied extensively over many decades and are well documented in the literature. However, the majority of the work reported in these areas is generally related to conventional concrete slabs subjected to highly idealized loading conditions.

Structural engineers need to find new, innovative ways and methods to design new structures but also to strengthen existing infrastructure to ensure safety, resilience, and sustainability. These challenges can be addressed through the use of integrated systems and high-performance technologically advanced materials. We live in a new era of improved computational capabilities, advances in high-performance computing, numerical and experimental methods, and data-driven techniques, which give us broader access to larger and better data sets and analysis tools. These new advancements are essential to develop deeper insights into the structural behavior of concrete slabs under punching shear and to implement and analyze new materials and loading conditions.

This Special Publication presents recent punching shear research and insights relating to topics that have historically received less attention in the literature and/or are absent from existing codified design procedures. Topics addressed include the usage and impacts of alternative/modern construction materials (new concrete and concrete-like materials, nonmetallic reinforcement systems, and combinations thereof) on slab punching shear resistance, novel shear reinforcement or strengthening systems, the influence of highly irregular/nonuniform loading and support conditions on slab punching shear, impact loading, new design and analysis techniques, and the study of the punching shear behavior of footings.

This Special Publication will be of interest to designers who are often faced with punching-related design requirements that fall outside of traditional research areas and existing code provisions, as well as for researchers who are performing research in related areas.

Perspectives from a broad and international group of authors are included in this Special Publication, relating to a variety of punching-related problems that occur in research and practice. In particular, researchers from the United States, Canada, Ecuador, the Netherlands, Italy, Brazil, Israel, Portugal, Spain, the United Arab Emirates, and Germany contributed to the articles in this Special Publication.

To exchange views on the new materials, tests, and analysis methods related to punching, Joint ASCE-ACI Committee 421, "Design of Reinforced Concrete Slabs;" Joint ASCE-ACI Committee 445, "Shear and Torsion;" and subcommittee ACI 445-C, "Punching Shear," organized two sessions titled "Punching shear of concrete slabs: insights from new materials, tests, and analysis methods" at the ACI Spring Convention 2023 in San Francisco, CA. This Special Publication contains several technical papers from experts who presented their work at these sessions, in addition to papers submitted for publication only.

Co-editors Dr. Katerina Genikomsou, Dr. Trevor Hrynyk, and Dr. Eva Lantsoght are grateful for the contributions of the authors and sincerely value the time and effort of the authors in preparing the papers in this volume, as well as of the reviewers of the manuscripts.

Aikaterini Genikomsou, Trevor Hrynyk, and Eva Lantsoght
Co-editors

Currently in preview, click buy full version

TABLE OF CONTENTS

SP-357-1:

Effect of the Shear Reinforcement Anchorage and Detailing on the
Punching Resistance of Flat Slabs..... 1-18

Authors: Guilherme S. Melo, Maurício P. Ferreira, Henrique J. Lima, Manoel M. Pereira-Filho, Victor H. Oliveira, João P. Siqueira, and Rodolfo Palhares

SP-357-2:

Punching Capacity of Spread Footings Using ACI 318-19 and the Strip Model..... 19-40

Authors: Scott Alexander, Carlos Ospina, and Eva Lantsoght

SP-357-3:

Review of Key Parameters Affecting Punching Shear Strength of Post-Tensioned Slabs 41-61

Authors: Madhura Sanjay Chavan and Mary Beth Hueste

SP-357-4:

New Insights into Punching Shear under Impact Loading.....62-76

Authors: D. Z. Yankelevsky, V. R. Fledgun, and Y. S. Karinski

SP-357-5:

Long-Term and Corrosion Effects on the Punching Shear Resistance of RC Flat Slabs

Subjected to Sudden Column Loss 77-99

Authors: Simone Ravasini, Francesca Vecchi, Beatrice Bellotti, and Nicolò Bonati

SP-357-6:

Shear and Punching Capacity Predictions for Slabs under Concentrated

Loads Aided by LEFEA.....100-122

Authors: Alex de Sousa, Eva Lantsoght, Andri Setiawan, and Mounir El Debs

SP-357-7:

Seismic Behavior of Slab-Column Connections Using High Performance

Fiber Reinforced Concretes..... 123-138

Authors: António Ramos, Brisid Isur, and Rui Marreiros

SP-357-8:

Punching-Shear Strength of Reinforced Concrete Slabs Subjected to Concentric

Transverse Loads and In-Plane Tensile Forces..... 139-159

Authors: Antonio Maria Pablo G. Fernández, Eva Oller, and Antoni Cladera

SP-357-9:

Punching Shear in Prestressed Concrete Deck Slabs: A Comprehensive Study 160-186

Author: Sana Amir, Cor van der Veen, Joost Walraven, and Ane de Boer

SP-357-10:

Influence of Slab Openings on the Punching Shear Behavior of Reinforced

Concrete Slabs Supported on L-Shaped Columns 187-221

Authors: Graeme J. Milligan and Maria Anna Polak

SP-357-11:

Nonlinear FEA of Flat Plates with Non-Uniform Connection Stresses 222-239

Authors: Reza Abolhelm and Trevor D. Hrynyk

SP-357-12:

Influence of Unbalanced Moment on Punching Shear Behavior of Footings 240-255

Authors: Jan Ungermann, Matthias Kalus, and Josef Hegger

Currently in preview, click buy full version

EFFECT OF THE SHEAR REINFORCEMENT ANCHORAGE AND DETAILING ON THE PUNCHING RESISTANCE OF FLAT SLABS

Guilherme S. Melo, Maurício P. Ferreira, Marcos H. Oliveira, Henrique J. Lima, Manoel M. Pereira-Filho, Victor H. Oliveira, João P. Siqueira and Rodolfo Palhares

Synopsis: Flat slabs with shear reinforcement not properly detailed and anchored as stated by ACI have been used in practice due to simplicity and the gained construction speed. This paper presents the results of 12 tests on slab-column connections with closed stirrups with anchorage variation and prefabricated truss bars as punching shear reinforcement. The behavior of the slabs, in terms of cracking pattern, displacements, and shear reinforcement strains, were analyzed, and ultimate loads were compared with estimations by ACI 318-19. Comparisons with the reference slabs without shear reinforcement showed that these two types of shear reinforcement effectively increased the load-carrying capacity of the tested slabs. For tests on slabs with closed stirrups, it was observed that if ACI detailing rules are followed, improvements in response and ductility of the slab-column connections should be expected. In the case of the slabs with prefabricated truss bars, it was observed that they were able to reach levels of punching shear resistance close to those of a reference slab with well-anchored stud rails. In both cases, further experimental research is needed. ACI 318-19 presented safe strength predictions for the different types of shear reinforcement tested, and in the case of the prefabricated truss bars, this was due to the conservative limitations imposed for calculating the crushing strength of the concrete strut close to the column.

Keywords: Closed stirrups, Experimental analysis, Flat slabs, Punching shear results, Prefabricated truss bars, Shear reinforcement, Shear reinforcement anchorage, Stud rail.