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Recent Developments in Two-Way Slabs: Design, Analysis, Construction, and Evaluation

Editors:
Mustafa Mahamid and Myoungsu (James) Shin

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Preface

During the last couple of decades, there have been new developments on the design and analysis of two-way slab systems, particularly associated with safety issues against earthquakes. In regard of the recent developments, Joint ACI-ASCE Committee 421 published a comprehensive state-of-the-art report, “Guide to Design of Reinforced Two-Way Slab Systems (ACI 421.3R-15)”, with indebted contributions from many dedicated members. To appreciate this achievement, Committee 421 organized two technical sessions titled, “Two-Way Slab Systems: Recent Developments and Showcases on Design, Analysis, Construction, and Evaluation Methods”, which were held at previous ACI Conventions on November 2015 in Denver, CO, and April 2016 in Milwaukee, WI. The presentation topics included new design and construction methods in two-way slab systems; innovative reinforcement methods for punching shear prevention; practical design and analysis experiences in recent projects of complex geometries; showcases on serviceability and maintenance issues encountered in RC or PT slabs; experimental tests and/or numerical modeling against extreme hazards, such as earthquake, fire, blast, and progressive collapse; and nondestructive evaluation techniques for in-place two-way slabs.

This Special Publication is a grateful outcome of the two technical sessions. The co-editors, Dr. Mustafa Mahamid and Dr. Myoungsu (James) Shin, sincerely thank and congratulate all the authors for their valuable contributions to the literature.

Mustafa Mahamid and Myoungsu (James) Shin
Co-Editors

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PLASTIC MODEL FOR ASYMMETRICALLY LOADED REINFORCED CONCRETE SLABS

Eva O. L. Lantsoght, Cor van der Veen and Ane de Boer

Synopsis: Most methods for the design and analysis of reinforced concrete slabs for punching are based on experiments on slab-column connections, reflecting the situation in building slabs. Slab-column connections with unbalanced moments have also been studied in the past. Experiments indicate that the accuracy of models for asymmetrically loaded slabs is lower than for symmetrically loaded slabs. In this paper, the difference in accuracy between test predictions for symmetrically and asymmetrically loaded slabs is tackled. A plastic model, the Extended Strip Model, is proposed. The results of maximum loads according to this model are compared to experimental results of symmetrically and asymmetrically loaded slabs. The comparison between the proposed Extended Strip Model and the experimental results shows that the model has a consistent performance for both symmetrically and asymmetrically loaded slabs. Moreover, the model has as an advantage that it combines the failure modes of flexure, shear and punching. The proposed model can be used for the analysis of slabs. In particular, it can be used for the assessment of existing slab bridges subjected to concentrated live loads.

Keywords: asymmetrically loaded slabs; extended strip model; flexure; one-way slabs; plasticity; punching; reinforced concrete slabs; shear; symmetrically loaded slabs.

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INTRODUCTION

Because of constraints in space and available loading, punching of slabs is typically studied with slab-column connections (ASCE-ACI Task Committee 426, 1974). This type of test setup reflects the situation in building slabs. As a result, the available code equations are either (semi-)empirical methods derived from a statistical analysis of slab-column connection tests, or based on mechanical models, verified with slab-column connection tests.

For the one-way shear capacity of beams, the situation is similar. Experiments are typically carried out on small, slender, heavily reinforced concrete beams tested in three- or four-point bending (Reineck et al., 2013). The available code equations are either (semi-)empirical methods derived from a statistical analysis of these tests, or based on mechanical models and verified with the available tests.

When the shear capacity of reinforced concrete slab bridges is assessed, both the beam shear (one-way shear) and punching shear (two-way shear) capacity under the combination of distributed dead loads and the prescribed live loads (typically distributed lane loads and concentrated loads from the design truck or tandem) need to be verified. This loading situation is different from a slab-column connection or simplified beam shear test setup, and is an asymmetrical loading situation because of the different positions of the design trucks or tandems over the lanes.

An asymmetrical loading condition that is studied for building slabs is the case of slab-column connections with unbalanced moments (Barzegar et al., 1991), reflecting the loading situation at edge and corner columns. The unbalanced moment is then considered to cause a contribution to the occurring shear stresses on the punching perimeter that needs to be summed with the direct shear stress on the punching perimeter, and the code methods reflect this approach.

RESEARCH SIGNIFICANCE

The presented study considers the shear capacity of symmetrically and asymmetrically loaded reinforced concrete slabs. Traditionally, the shear capacity is considered as the one-way shear capacity and the two-way shear capacity separately. In this paper, a plastic model is described, the Extended Strip Model, and the applicability to both symmetrically and asymmetrically loaded reinforced concrete slabs is highlighted. Experimental results show the validity of the presented model.

LITERATURE REVIEW

Existing methods for the shear capacity of slabs

One-way shear models — The shear capacity of beams without transverse reinforcement (the situation that occurs when considering the one-way shear capacity of slabs) has been fiercely debated over the past century, and a multitude of (semi-)empirical and mechanical models have been developed. The code provisions, which result from semi-empirical models based on a statistical analysis, will be discussed in the next section. In this section, mechanical models are discussed.

The first approach is the Modified Compression Field Theory (Vecchio and Collins, 1986), which has been adopted into the Canadian building provisions CSA A23.3 (Canadian Standards Association, 2004), AASHTO LRFD Code (AASHTO, 2015) and the *fib* Model Code (fib, 2012), replacing in these codes the semi-empirical formulations with a mechanical model for the first time. In the Modified Compression Field Theory and the Simplified Modified Compression Field Theory (Bentz et al., 2006), the constitutive relations of cracked concrete are used, based on average stresses and strains. For members without transverse reinforcement, concrete tension ties resulting from