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Some Tests on the Punching Shear Strength of Reinforced Concrete Slabs Punching shear in reinforced concrete state of the art report *Punching shear of structural concrete slabs* Punching Shear in Reinforced Concrete Slabs **Punching Shear Strength of Wood Chipboard Punching Shear Strength of Slab-column Connections in Reinforced Concrete Punching Shear Strength of Reinforced Concrete Slab** *Punching Shear Strength of High Strength Reinforced Concrete Slabs* **Influence of Size on Punching Shear Strength of Concrete Slabs** Punching Shear Strength of Reinforced High Strength Concrete Slabs Punching Shear Strength of Steel Fiber Reinforced Concrete Flat Plates Punching Shear Strength of Thin Reinforced Concrete Elements Punching Shear Strength of Reinforced Concrete Flat Slabs at Edge Columns *Characterization of the Punching Shear Capacity of Thin Ultra-high Performance Concrete Slabs* **Punching Shear Strength of Slab-column Connections in Flat Plate System Punching Shear Strength of Post-tensioned Concrete Flat Plates with L-shaped Column** *Effect of Fibers on the Punching Shear Strength of Reinforced Concrete Slabs* **Punching Shear Strength at Edge Columns in Ribbed Flat Slabs** Combined Punching Shear and Torsional Shear in Reinforced Concrete Slabs **Punching Shear Strength of GFRP-Reinforced Flat Slabs Structures Punching Shear Strength of Edge Column Connections of Rectangular Flat Plates Effect of Slab Thickness on Punching Shear Strength** Punching Shear Strength and Drift Capacity of Slab-column Connections with Headed Shear Stud Reinforcement Subjected to Combined Gravity Load and Biaxial-lateral Displacements *Punching Shear Strength of Steel Fibre Reinforced Lightweight Concrete Slabs* **Punching Shear Strength of Reinforced Concrete Flat Plates with Spandrel Beams** Punching Shear Strength of Reinforced Concrete Bridge Deck Slabs *Punching Shear Strength of Waffle Slabs at Internal Columns Punching Shear Strength of Slabs with Openings and Supported on Rectangular Columns* **SP-353: Design of Slabs for Serviceability and Punching Shear Strength: Honoring Professor Amin Gh Finite Element Analysis of Punching Shear Strength of Reinforced Concrete Structures** Shear and Punching Shear in RC and FRC Elements *Punching Shear Strength of Interior and Edge Column-slab Connections in CFRP Reinforced Flat Plate Structures Transferring Shear and Moment* Punching Shear Strength of Unbonded Prestressed Flat Slabs at Edge Column Connections Punching Shear Strength of Continuous Post-tensioned Concrete Flat Plate *Statistical Analysis and Modeling of Test Results for Punching Shear of Concrete Slabs Around Square Columns* **Punching Shear Strength of Reinforced and Post-tensioned Concrete Flat Plates with Spandrel Beams Punching of Structural Concrete Slabs Punching Shear Strength of Ferrocement Bolted Sandwich Panel Slabs** Punching Shear Strength of Waffle Slabs at Internal Colu **How to Design Concrete Structures Using Eurocode 2**

This study summarizes experimental results of the punching shear behavior of reinforced concrete slab-column connections containing fiber reinforcement. Fiber reinforcement is particularly attractive and beneficial for concrete, especially where shear stresses are involved. Tests are reported on simply supported slab specimens loaded through a stub column to study the effect of several parameters, namely, type, volume, fraction, and aspect ratio of fibers. The experimental tests on reinforced concrete slabs showed that fiber reinforcement can contribute significantly to the enhancement of punching shear strength and ductility of concrete structural members. This increase is function of the fiber volume and fiber type. A simple empirical relationship describing the effect of steel fibers on the punching shear strength of slab-column connections is derived based on the results of this test and other experimental results reported in technical literature. fib Bulletin 81 reports the latest information available to researchers and practitioners on the analysis, design and experimental evidence of punching shear of structural concrete slabs. It follows previous efforts by the International Federation for Structural Concrete (fib) and its predecessor the Euro-International Committee for Concrete (CEB), through CEB Bulletin 168, Punching Shear in Reinforced Concrete (1985) and fibBulletin 12, Punching of structural concrete slabs (2001), and an international symposium sponsored by the punching shear subcommittee of ACI Committee 445 (Shear and Torsion) and held in Kansas City, Mo., USA, in 2005. This bulletin contains 18 papers that were presented in three sessions as part of an international symposium held in Philadelphia, Pa., USA, on October 25, 2016. The symposium was co-organized by the punching shear sub-committee of ACI 445 and by fib Working Party 2.2.3 (Punching and Shear in Slabs) with the objectives of not only disseminating information on this important design subject but also promoting harmonization among the various design theories and treatment of key aspects of punching shear design. The papers are organized in the same order they were presented in the symposium. The symposium honored Professor Emeritus Neil M. Hawkins (University of Illinois at Urbana-Champaign, USA), whose contributions through the years in the field of punching shear of structural concrete slabs have been paramount. The papers cover key aspects related to punching shear of structural concrete slabs under different loading conditions, the study of size effect on punching capacity of slabs, the effect of slab reinforcement ratio on the response and failure mode of slabs, without and with shear reinforcement, and its implications for the design and formulation in codes of practice, an examination of different analytical tools to predict the punching shear response of slabs, the study of the post-punching response of concrete slabs, the evaluation of design provisions in modern codes based on recent experimental evidence and new punching shear theories, and an overview of the combined efforts undertaken jointly by ACI 445 and fib WP 2.2.3 to generate test result databanks for the evaluation and calibration of punching shear design recommendations in North American and international codes of practice. Punching shear often controls the required slab thickness or column size of flatplate slabs. This paper presents the results of an experimental investigation of the punching shear strength of post-tensioned concrete slabs with rectangular and L-shaped columns. The test results are compared with ACI equations for punching shear strength. An analysis accounting for the cracking at the critical sections is also presented which provided a better prediction of the punching shear strength. Good correlations between what was predicted and the actual experimental results have been achieved. The lack of supplementary bonded reinforcing steel in regions of moment transfer had no apparent detrimental effects so it must be concluded that the prestress was effective right to the edge of the concrete. The use of 100% banded tendons in one direction and uniform distribution in the other direction had no adverse effects on either the flexural or punching shear behaviour. Ultra-high performance concrete (UHPC) is a relatively new type of concrete that exhibits mechanical properties that are far superior to those of conventional concrete and in some cases rival those of steel. The main characteristics that distinguish UHPC from conventional reinforced concrete are its very high compressive strength (20 to 33 ksi), the addition of steel fibers which enables tension to be carried across open cracks without conventional reinforcing steel, and a very high resistance to corrosion and degradation. The mechanical properties of UHPC allow for smaller, thinner sections as compared to conventional reinforced concrete sections. However, as it is a new material, the use of UHPC has been limited to a few structural applications due primarily to the high cost of the material and the lack of established design guidelines. In previous research, a material model based on physical tests was used in conjunction with finite element models to develop an optimized cross-section for a prestressed UHPC girder for bridge applications. The cross-section is a double-tee with bulbs at the bottoms of the webs to accommodate the prestressing strands. As it is envisioned in bridge applications, the double-tees will be placed directly adjacent to one another, and the top flange will act as the riding surface after a thin asphalt overlay is placed. Based on the longitudinal compressive stresses, the top flange of the girder can be quite thin. However, there exists the possibility that a punching shear failure could occur from the application of a point load such as a wheel patch load if the flange is made too thin. The research reported herein was initiated to characterize the punching shear capacity of thin UHPC plates and to develop recommendations on the minimum top flange thickness for the optimized double-tee. Twelve small slabs (45 in x 45 in) were tested to failure to characterize the punching shear strength of UHPC. The variables considered were the slab thickness (2, 2.5, and 3 in) and loading plate dimensions (from 1 in x 1 in to 3 in x 3 in). The results of the testing were compared to several existing models for punching shear. The two equations that predicted strengths most reliably were the current ACI punching shear equation and a modified bolt pull-out equation. After evaluation of the test results, the minimum slab thickness required to prevent a punching shear failure in the top flange due to an 8 in x 20 in wheel patch was determined to be 1 in. Three larger slabs were also tested. These slabs had the same clear span length as the top flange of the optimized double-tee and were loaded with a wheel patch load. The slabs were all approximately 3 in thick and all failed in flexure rather than punching shear. It was concluded that the casting method has a strong influence on the orientation of the steel fibers, which in turn influences the flexural strength in orthogonal directions in the slab. The top flange thickness will be governed by transverse bending rather than punching shear, and the 3 in slabs were not able to support the full wheel load plus impact and load factor. The results of this research help in the continued optimization of a UHPC shape for use in highway bridges. If material use in the girder is minimized, UHPC bridges can become economically competitive with HPC bridges, but offer the benefits of more rapid construction and better durability. fib Bulletin 57 is a collection of contributions from a workshop on "Recent developments on shear and punching shear in RC and FRC elements", held in Salò, Italy, in October 2010. Shear is one of a few areas of research into fundamentals of the behaviour of concrete structures where contention remains amongst researchers. There is a continuing debate between researchers from a structures perspective and those from a materials or fracture mechanics perspective about the mechanisms that enable the force flow through a concrete member and across cracks. In 2009, a Working Group was formed within fib Task Group 4.2 "Ultimate Limit State Models" to harmonise different ideas about design procedures for shear and punching. An important outcome of this work was the ensuing discussions between experts and practitioners regarding the shear and punching provisions of the draft fib Model Code, which led to the organization of the Salò workshop. Invited experts in the field of shear and FRC gave 18 lectures at the workshop that was attended by 72 participants from 12 countries in 3 different continents. The contributions from this conference as compiled in this bulletin are believed to represent the best of the current state of knowledge. They certainly are of general interest to fib members and especially helpful in the finalization of the 2010 fibModel Code. It is hoped that this publication will stimulate further research in the field, to refine and harmonize the available analytical models and tools for shear and punching design. A statistical regression analysis was conducted on 146 selected test results from the literature to evaluate the basic ACI318 two-way shear strength equation, which has not changed since 1963. The basic ACI318 shear equation was established based on a statistical analysis of test results on scaled slab samples that were believed to have failed in shear. Only slabs with square columns, sheared on four sides and without shear reinforcement were needed in this study, resulting in 146 selected test results from 1956 to 2014. The study included slabs with normal and high strength concrete. This study presents new equations for slab punching shear capacity. The effect of several parameters on the punching shear strength is also discussed in this study. A simplified practical punching shear equation is also proposed based on statistical analysis of the experimental results from the database. The new proposed equations include the reinforcement ratio of the slab and the cubic root of the concrete strength. The study also showed that including the reinforcement ratio in the punching shear equation increases its accuracy. The new proposed equations are valid for normal and high strength concrete slabs. Punching is considered to be one of the most difficult problems in structural concrete design and mechanical models or theoretical analyses were developed rather late in the history of concrete research attempts. This fib Bulletin reviews the development of design models and theoretical analyses since the CEB Bulletin 168 Punching Shear in Reinforced Concrete - State-of-the-Art Report published in 1985. The role of the concrete tensile strength was specially addressed. In this respect the present bulletin is also following-up the CEB Bulletin 237 Concrete Tension and Size Effects - Utilisation of concrete tension in structural concrete design and relevance of size effect - Contributions from CEB Task Group 2.7 published in 1997. Apart from new theoretical developments a comprehensive databank for comparisons with experimental evidence is included. About 400 punching tests were critically reviewed and evaluated in a consistent manner. This is thought to be the first step towards a generally agreed selection of reliable tests. The evident value of such a data bank is illustrated by comparisons carried out between the data and some of the analytical proposals as well as empirical code formulas. List of contents : (1) Introduction, (2) Code equations, (3) Mechanical models for punching, (4) New developments for mechanical models, (5) Numerical investigations, (7) Comparison of mechanical models and test results of slabs without shear reinforcement, (8) Comparison of code rules and tests of flat slabs without shear reinforcement, (9) Comparison of codes, models and tests of flat slabs with shear reinforcement, (10) Experimental investigations, (11) Summary and conclusions, References, Appendices : (I) Databank on slabs without shear reinforcement, (II) Databank on slabs with shear reinforcement, (III) Comparison of test data with code rules, (IV) Comparison of test data with selected models, (V) Notations.