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Guest Editorial

Punching shear capacity of RC slabs

Since early sixties, lot of research has been devoted to punching shear capacity of reinforced concrete slabs. During recent years developments in both material technology and computer aids have had a major influence also in this part of structural engineering. Prestressing steel, post-tensioning, steel fibre reinforced concrete, lightweight concrete, and high strength concrete have been used also in slabs on columns. Modern and efficient computers make it possible to refine the calculations including both non-linear material behaviour and fracture mechanics. Today, the development in the area of punching is going fast in many places around the world, but simultaneously, there is a need of increased harmonisation, not least within the transition of Eurocode 2 from ENV to EN. Very recently, fédération internationale du béton (fib) published a state-of-the-art report on punching of structural concrete slabs. [1] Beside descriptions of codes, mechanical models, numerical investigations, and comparisons, it comprises a databank containing more than 400 slab tests from 1956.

The Department of Structural Engineering at Royal Institute of Technology (KTH) in Stockholm, Sweden, has played an important role within this field during four decades under the guidance of the late *Prof. Henrik Nylander* and his successor *Prof. Sven Kinnunen*. To celebrate *Prof. Sven Kinnunen's* 70th birthday, an international workshop was organised in June 2000 in Stockholm. The response of the workshop was overwhelming. The proceedings [2] contain 54 papers. Due to the large number of papers, the available space for each author had to be very limited. Despite efforts to advertise the proceedings, the number of readers is rather low compared to the number of readers of a scientific journal. Consequently, the Guest Editor was very happy to accept the offer from Cement and Concrete Composites' Editor to collect a Special Issue to Punching Shear Capacity of RC Slabs. It was a chance to give the authors of some of the most interesting workshop presentations more space to develop their ideas and spread them to a wider audience.

This Special Issue contains seven papers on punching shear capacity of RC slabs. In the first paper, *Dr. M. Hallgren* and *Mr. M. Bjerke*, *M.Sc.*, analyse punching shear failure of column footings using the finite elements method and a non-linear approach. The FE analyses agree well with available test results. This shows that modern analysis tools can be used to increase the understanding of the structural behaviour of punching shear and to improve the design methods.

The following two papers deal with analytical models. *Dr. Ph. Menétray* proposes an analytical model to compute the punching load. It is based on the integration of the vertical components of the tensile stressed around the punching crack and has its origin in careful observations on the structural behaviour of his own and other researchers' test slabs. The paper is a good example of the importance of combining tests, numerical analyses, and development of design methods. *Dr. D.D. Theodorakopoulos* and *Prof. R.N. Swamy* present another analytical model to predict the ultimate punching strength of slab-column connections. It has been used for lightweight and normal weight concrete and both normal strength and high strength concrete. A good agreement between computed and experimental results is obtained.

Building failures are very few due to the high safety margins that are used in design. It means that we rarely will see a failure outside the laboratory. A terrible exception was the 1995 collapse of the Sampong department store that killed 500 persons. In the forth paper in this Special Issue, *Prof. N.J. Gardner*, *Mr. Jungsuck Huh*, and *Prof. Lan Chung* have analysed the failure that had its origin in a slab-column connection. Some codes does not predict the failure, others do. The importance of considering the size effect and small reinforcement ratios is addressed. Various codes are also compared in the next paper. *Prof. U. Albrecht* discusses how two American and four European codes as well as the

[1] Punching of Structural Concrete Slabs. Bulletin No. 12, fédération internationale du béton (fib) Lausanne, Switzerland, 2001, 307 pp.

[2] Silfwerbrand J & Hassanzadeh G (Editors). Proceedings, International Workshop on Punching Shear Capacity of RC Slabs. Stockholm, Sweden, June 7–9, 2000. Bulletin No. 57, Royal Institute of Technology, Department of Structural Engineering, Stockholm, Sweden, 527 pp.

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CEB-FIP Model Code deal with punching. The provisions differ considerably among these codes. They have been developed in close connection to local tests and local construction practice regarding, e.g., flexural reinforcement, shear reinforcement, integrity reinforcement, and steel qualities. Hence, both design and construction will be governed by the code chosen to a high degree. Consequently, it is important that code writers consider these facts in order to promote design improvements without jeopardising safety.

The last two papers on punching shear capacity are devoted to the development of new technical solutions. *Mr. R. Beutel*, *M.Sc.*, and *Prof. J. Hegger* compare various systems of shear reinforcement. They show that the effectiveness of the shear reinforcement depends on the quality of the anchorage. In their experimental investigation, they found that replacing conventional stirrups with stirrups made out of fabric might lead to both higher punching shear capacity and reduced construction times. In the last paper, *Prof. M. Schnellenbach-Held* and *Mr. K. Pfeffer*, *M.Sc.*, introduce a new kind of hollow slab in the punching research. The slab contains plastic balls as hollow bodies reducing the weight with 30%. The paper covers laboratory tests, numerical simulations, and design considerations. The test results show that the introduction of the bubbles do not alter the failure mode of the slab. Minor modifications to the German code for punching resistance are suggested.

We may conclude that we cannot see an end of the research on punching shear capacity of RC slabs. Further development of models describing the material behaviour, improved computer methods, further material development, innovative reinforcing techniques, and new application fields will secure the continuation of this research in the 21st century.

Last but not least, the Guest Editor would like to express his thanks to the following reviewers for their efforts to secure a high standard of the papers: *Prof. Andrzej Ajdukiewicz*, Silesian University of Technology, Poland, *Dr. Prab Bhatt*, University of Glasgow, UK, *Dr. Mikael Brœstrup*, Rambøll, Denmark, *Prof. Jonas Holmgren*, Royal Institute of Technology (KTH), Sweden, *Prof. Sven Kinnunen*, KTH, Sweden, *Prof. Peter Marti*, Swiss Federal Institute of Technology, Switzerland, *Prof. Mogens P. Nielsen*, Technical University of Denmark, Denmark, *Prof. Marianna Polak*, University of Waterloo, Canada, *Prof. Julio Ramirez*, Purdue University, USA, *Prof. Paul Regan*, University of Westminster, UK, *Prof. Karl-Heinz Reineck*, University of Stuttgart, Germany, *Prof. Sven Sahlin*, KTH, Sweden, *Prof. Luc Taerwe*, Ghent University, Belgium, *Prof. Joost Walraven*, Delft University of Technology, The Netherlands, and *Adjunct Prof. Bo Westerberg*, Tyréns, Sweden.

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