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Punching shear strength of reinforced concrete slabs with plastic void formers

Juozas Valivonis, Tomas Skuturna *, Mykolas Daugevičius, Arnoldas Šneideris

Department of Reinforced Concrete and Masonry Structures, Vilnius Gediminas Technical University, Saulėtekio ave 11, 10223 Vilnius, Lithuania

HIGHLIGHTS

- A new type of plastic void formers is used.
- The reinforced concrete slabs with plastic void formers are designed.
- Experimental research of real scale biaxial voided slabs is performed.
- Comparison of the experimental and theoretical values of punching shear capacity is done.
- A method for calculating the perimeter of the equivalent punching zone is proposed.

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ABSTRACT

In order to reduce the amount of concrete and self-weight of flat slabs, plastic void formers are used in slabs. The most critical areas of flat slabs are slab–column junctions and the zones where huge concentrated loads act. This area is more prone to punching shear failure. The cross section of concrete in reinforced concrete slabs with plastic void formers is significantly smaller, and hence the punching shear capacity of such junctions is insufficient. This article discusses the results of an experimental and theoretical study that investigated the punching shear capacity of reinforced concrete biaxial voided slabs. In order to increase the punching shear capacity of flat slabs, shear reinforcement is provided between voids in the concrete ribs. Slabs with void-forming inserts placed in the entire slab area, voided slabs with solid cross shapes and voided slabs with solid heads were analysed in this study. A method to calculate punching shear capacity based on EC2 methodology has been proposed. The results obtained for the punching shear capacity of the experimental slabs were verified with the EC2 methodology, and a method to calculate the length of the punching shear perimeter has been proposed.

1. Introduction

Flat slabs are widely used in modern construction. The application of flat slabs is caused by simple structural solution and construction technology. Generally, to achieve long spans of flat slabs, the depth of cross section should be increased. In this case the self-weight of flat slabs and the amount of materials rises. In order to reduce the amount of concrete and self-weight of flat slabs, plastic void formers are used in slabs [1–3]. The behaviour of the slabs changes when the type or shape of inserts differs. When void formers are systematically introduced between such slabs, ribs are formed. The most effective way is placing plastics void formers up to slab–column junctions. The most dangerous areas of biaxial solid and biaxial voided slabs are the slab–column junctions and zones where concentrated loads act [4]. Huge shear stresses in this area cause punching of the concrete [5–7]. Furthermore, voided slabs are more susceptible to punching shear failure than solid slabs. Research has shown that the blanking angle of the punching failure surface of the cone punched out while punching the slab ranges from 22° to 45°. The punching shear capacity may be enhanced by reinforcing the punching area with shear reinforcement [8–11]. Also the punching area can be reinforced with fibre reinforced reinforcement (FRP). The punching area of voided slab also can be reinforced with shear reinforcement. Possibly, the shear reinforcement can be provided in the ribs.

Solid slabs and solid slab–column junctions have been studied intensively [12–14]. Based on these studies, different methods have been proposed for calculating the punching shear capacity of a slab [15–17]. But these methods are based on different

* Corresponding author.
E-mail addresses: juozas.valivonis@vgtu.lt (J. Valivonis), tomas.skuturna@vgtu.lt (T. Skuturna), mykolas.daugevicius@vgtu.lt (M. Daugevičius), arnoldas.sneideris@vgtu.lt (A. Šneideris).

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Table 1
Properties of concrete.

Slab	Sample, mm	f_c, MPa	E_{cm}, GPa
BPR1	Cube, 150 × 150 × 150	31.64	–
BPR1	Cylinder, ø150, h = 300	26.51	27.17
BPR2	Cube, 150 × 150 × 150	34.78	–
BPR2	Cylinder, ø150, h = 300	28.95	25.57
BPR3	Cube, 150 × 150 × 150	32.02	–
BPR3	Cylinder, ø150, h = 300	27.96	24.2

Table 2
Properties of reinforcement.

Diameter	A_s, m^2	f_y, MPa	E_s, GPa
6	$0.3323{\cdot}10^{-4}$	397.71	207.06
8	$0.482{\cdot}10^{-4}$	519.50	203.06
14	$1.5589{\cdot}10^{-4}$	559.00	191.83

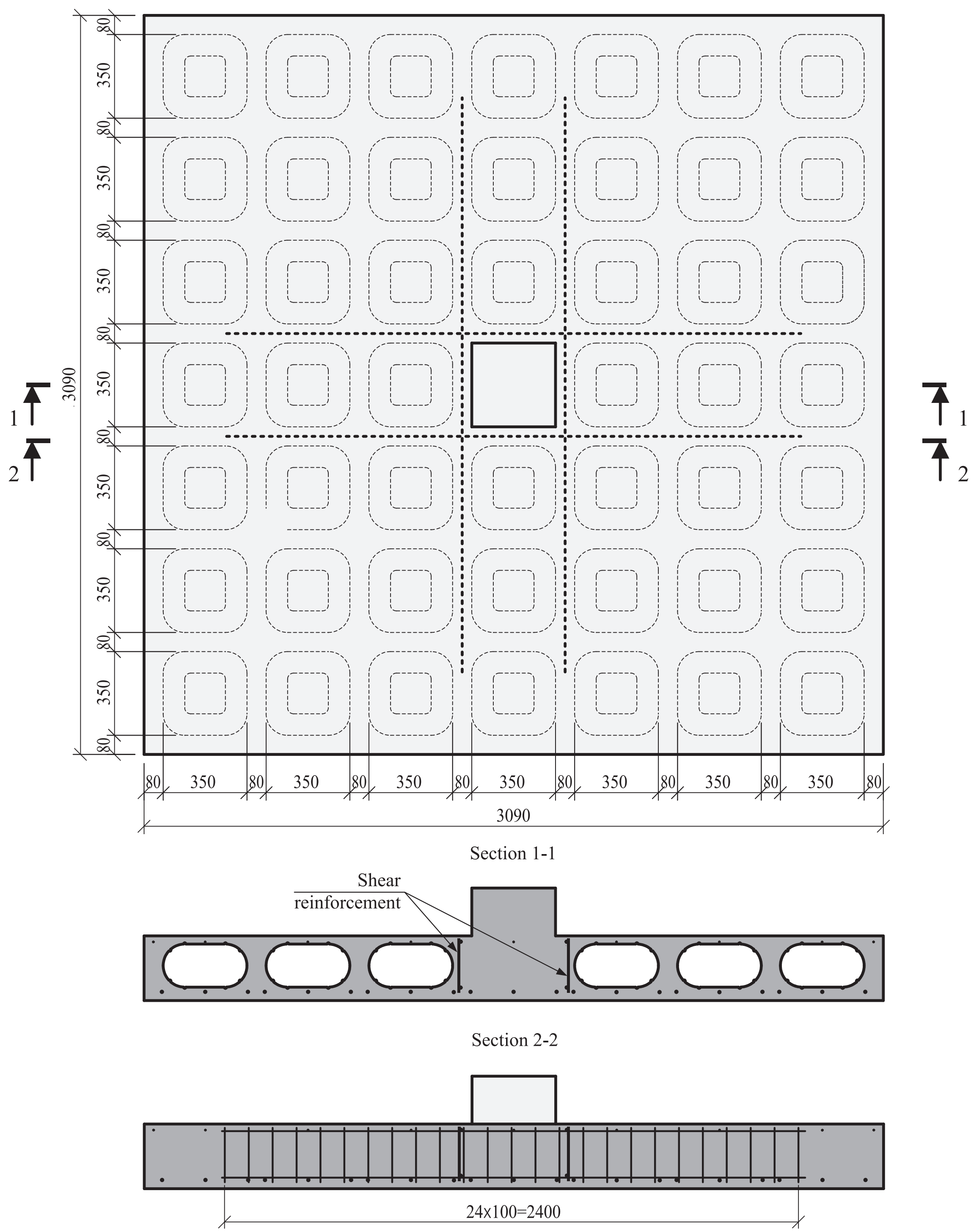

Fig. 1. Geometry and reinforcement of the specimens BPR1-1 and BPR1-2: plan and section.