Innovative bionic design of flat slabs

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Abstract

This scientific paper describes a bionic optimization of flat slabs. Emphasis is placed on the load bearing capacity, but sustainability and efficiency aspects are also considered. Previous investigations show that slabs enhanced by nature can lead to considerable material saving without loss of bearing capacity. This paper presents the results of extensive test work to optimize the punching shear resistance of flat slabs inspired by natural systems. In this case the reinforcement is positioned stress-oriented, so that a spider web-like reinforcement arrangement is created. The results of the numerical simulations show that in comparison to orthogonally reinforced slabs an increased load capacity with a smaller reinforcement ratio can be achieved.

Keywords: optimization; bionic; flat slab; punching; reinforcement configuration.

1 Introduction

The reinforced concrete flat slab represents the standard construction method in commercial buildings due to the advantages of flexibility, construction speed and low formwork costs. Optimizing the slab can lead to considerable cost and material savings for the entire building. The share of slabs in the total concrete cubature is about 50 to 60% [1] and the cost share of the slabs amount up to 15% of the total construction costs [2]. Reducing the mass of the ceiling structure has a positive effect on the weight of the structure (correspondingly lower loads) as well as on the life cycle assessment of the building (less embodied energy). The entire built environment (building and civil engineering construction plus infrastructure) accounts for 50% of resource consumption and 50% of mass waste volume in Central Europe [3]. In addition, the built environment is responsible for about 35% of energy consumption and 35% of emissions [3]. Therefore researchers at the Institute of Structural Concrete of the University of Duisburg-Essen look for various optimization options for slabs.

2 Structural system of flat slabs

In flat slabs the main moments under steady load are shown in Figure 1. The negative moments are situated around the supports radially and tangentially. The main bearing direction is based on the shortest connections between the support points and fans out with increasing curvature. The design of flat slabs is governed by deflections control in the span (serviceability limit state) on the one side and by the resistance of punching shear of column-slab nodes (ultimate limit state) on the other side. These two criteria are decisive to select the appropriate slab thickness.

In both cases, the degree of longitudinal reinforcement with the largest possible lever arm is of crucial importance. The deformations are also significantly influenced by the stiffness of the concrete (modulus of elasticity, shrinkage, creep and cracking behaviour), while the punching shear resistance depends strongly on the concrete strength (three axial compressive stress behaviour, shear cracking).

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