Influence of the vertical component of the tendons on punching resistance of prestressed flat slabs

Generally, in a prestressed flat slab, lateral forces produced by a change in tendon direction develop above the column. If these forces are directly introduced into the column, they do not generate any punching-relevant shear forces. The sum of the vertical components of the deflection forces above the column can be deducted from the acting load. For constructional reasons, not all prestressed tendons are arranged directly above the column, but placed laterally. For the punching design according to DIN 1045-1, all tendons inside the basic control perimeter may be taken into account. Up to now, it has not been clarified whether the tendons placed at a larger distance are able to introduce their vertical deflection forces directly into the column without stressing the punching area.

In this research project, the influence of the vertical component of the tendons on the punching resistance was investigated by numerical simulations and by evaluating tests known from literature.

Two parameter studies were carried out regarding the influence of the vertical components of the tendon on the punching resistance. At first, the course of the tendon was varied in longitudinal direction. It turned out that the ultimate load decreases with increasing distance of the point of contraflexure to the column face. The observed reduction of ultimate load could not be explained by the vertical component of the tendon increasing in the direction of the column; it is, however, proportional to the bending of the slab at the column face due to prestressing.

In the second part of the parameter study, the tendons were positioned laterally next to the column at different spacings. As was to be expected, in the numerical simulation, the punching shear capacity of the slab decreased with increasing distance of the tendons to the column face. However, there was no abrupt decrease, but with increasing distance to the column face the punching shear capacity was constantly reduced. Also in this parameter study, it could be demonstrated that the punching resistance depends on the bending of the slab due to prestressing. However, a bilinear correlation occurs that indicates the existence of additional load bearing mechanisms.

To examine the results of the numerical simulation, tests known from literature were analysed according to DIN 1045-1. An adequate safety level could be yielded in almost all tests without punching shear reinforcement independent of the course of the tendon. Complying with the recommendation in Book 525 of DAfStB, in tests with punching shear reinforcement and prestressing on the level of the maximum punching shear capacity an application of the normal stress should be waived.

Although the determination of the vertical component according to DIN 1045-1 at a spacing of 1,5d from the column face correctly describes the mechanical effect of the prestressing only in exceptional cases (depending of the course of the tendon), it is not necessary to change this established method on the basis of the conducted investigations. According to the results of the numerical simulation as well as to the analysis of the database, the increase in ultimate load due to prestressing is controlled by the bending of the slab resulting from prestressing. To consider this correlation in practical design is, however, considerably more complex than the determination of the vertical components of the inclination of the tendon.