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Punching Failure Mechanism of Composite Slab-Column Joints

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Summary

The idea of composite joints in slab-column skeletal structures deals with introduction of precast members from high-strength concrete as combined head-and-column elements. As behaviour of such joints under axial or eccentric loads has not been clarified, therefore the series of full-scale models of joints have been tested up to failure to obtain basic data about the failure mechanism.

1. Introduction

The carrying capacity of flat-plates without shear reinforcement is very often not sufficient, particularly at interior column supports. Recently, in such cases the column cross-section have been enlarged or the special shear reinforcement or steel inserts have been used to protect heavy stressed support zones against the rapid punching failure (see [1]).

On the other side, the tests of monolithic slab-column joints indicated the significant role of compressive strength and deformability of concrete in slab around the column face, where biaxial compression was stated [2]. Therefore, application of high-strength concrete should be considered as the simplest method of the zone strengthening [3],[4]. The idea of composite structure with precast head-and-column elements from HSC (e.g. C70 or C80) and the remaining parts of slab from ordinary concrete was proposed in the first row for simple multi-storey buildings, like car-parks [5]. At least two benefits in such buildings are expected: the support zones strong enough without additional shear reinforcement and reduction of column sections.

To introduce the idea into the practice some designers' doubts should be clarified. The behaviour of such joints up to failure as well as carrying capacity of joints must be tested on full-scale models (to omit the size effects). Synthesis of observations from the tests of first series of six models are presented in this paper.

2. Test Observations

In monolithic joints (Fig.1a) axisymmetrically loaded up to punching failure the shape of failure surfaces are always observed as truncated cones. The inclination α of basic crack depends mainly on the flexural reinforcement ratio and oscillate from 25^0 to 35^0.

In composite joints, in which the difference in concrete strength in members was not significant and both concretes were from the range of normal-strength concrete (e.g. C30 in head and C15 in slab) the behaviour at failure was very similar to that in monolithic joints (Fig.1b). The difference in failure crack was small: angle $\alpha \cong \beta$ from 32^0 to 36^0.

Quite different situation was recorded in tests of models with relatively strong heads - precast parts from concrete about C70 and monolithic slab from ordinary concrete C15. The failure was observed in two phases. The main top crack in slab occurred earlier at about 60% of ultimate load as a first phase of punching. The second phase was observed as sudden, noisy crack at the maximum recorded load. After cutting reinforcement the failure surface in the shape of double truncated cone was uncovered (Fig.1c). The angle α was from 40^0 to 48^0, while the angle β was from 19^0 to 21^0. The value of ultimate punching load in this case was about 10% greater than that in case presented in Fig.1b, at the same ratio of flexural reinforcement in both cases.

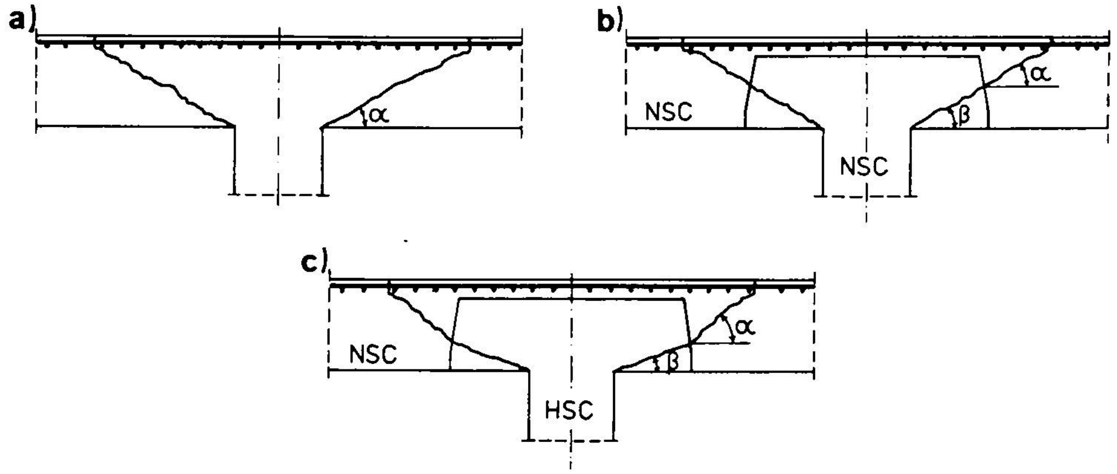

Fig.1. Recorded shapes of failure surface in axisymmetrical punching shear of models

3. Conclusions

The behaviour of composite slab-column joints with HSC head-and-column members was observed significantly different from that known from monolithic joints. The two-phase failure of such composite joints was recognized as more advantageous due to the warning signal than the increment in the final punching resistance.

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