Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 83 (1999)

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DOI: https://doi.org/10.5169/seals-62900

Punching of Flat Slabs – Comparison of Design and Construction

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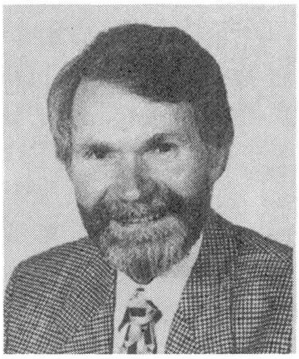


Uwe Albrecht, born 1940, received his civil engineering degree from the University of Hannover and his doctorate from the Technical University of Darmstadt. After 16 years in the construction industry he was appointed Professor of Structural Engineering in Buxtehude (near Hamburg) in 1983

Summary

The provisions for the design and construction of reinforced concrete flat slabs differ considerably. The punching provisions will be compared with respect to the shear capacity, the common shear resistance of concrete and shear reinforcement and the relevant detailing of the reinforcement specified in

Germany	DIN 1045
	E DIN 1045-1
Eurocode	EC 2
UK	BS 8110
USA	ACI 318
Canada	CSA A23.3
Model Code	CEB-FIP 1990

Keywords: Concrete structures, flat slabs, punching, shear resistance, shear reinforcement, integrity reinforcement

1. Shear resistance

The shear resistance is calculated on a critical perimeter u which is located $0.5d$ to $2d$ from the face of the column (d.... effective depth, h....overall thickness). Fig. 1 shows the location for an interior column with rectangular cross-section $c_1 \cdot c_2$. Some codes require that the shear resistance outside the shear reinforced zone should be checked at successive perimeters u_2, u_3.

The shear resistance is expressed by
V_{Rd1} ....provided by the concrete
V_{Rd2} ....maximum shear resistance with shear reinforcement, the capacity is limited by the concrete strength of the struts
Fig. 2 results from the material data of C35 (cube) or C30 (cylinder) and the assumption
$d = 0.85\ h$ $\alpha = (c_1 + c_2) / 2\ h$

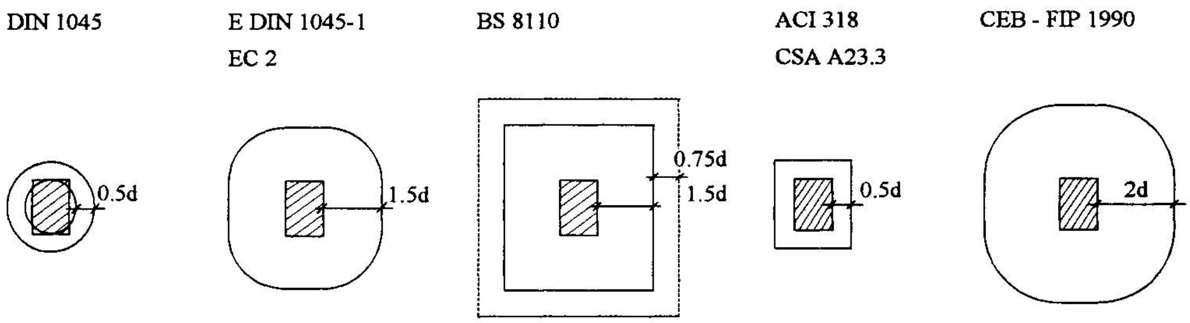
All codes, with the exception of DIN 1045, use partial safety factors which are, however, not identical. Therefore the comparison is based on service loads. For simplification, a common safety factor γ_F for permanent (G_k) and imposed load (Q_k) has been chosen for each code and the size factor refers to d = 25cm.

With shear reinforcement, the shear capacity may be enhanced up to $\approx 40\%$ according to DIN 1045 or up to a maximum of >60% according to BS 8110 and CEB-FIP 1990. Fig. 3 shows the shear reinforcement required for V_{Rd2}, assuming a yield stress of $f_{yk} = 500$ N/mm². For better comparison, the shear resistance specified in BS 8110 and CEB-FIP 1990 has been limited to $V_{Rd2} = 1.6\ V_{Rd1}$.

2. Conclusions

The paper reveals on the one hand considerable differences with respect to the shear capacity and to the amount and fitting of shear reinforcement and integrity reinforcement and on the other hand that design and detailing form an integral whole. The different effect of the flexural reinforcement ratio on the shear capacity is remarkable, particularly as the North American codes do not take the reinforcement ratio into account at all.

The rules for the common shear resistance of concrete and the shear reinforcement are manifold because of the different assessment of the effectiveness of the shear reinforcement. There is a need for tests to overcome this contradiction. Some codes require an integrity reinforcement provided by continuous bottom bars passing within the column cage to prevent progressive collapse of the structural system in the case of local punching. Others do not even mention this reinforcement.



DIN 1045: $d_{st} = 1.13\sqrt{c_1 c_2}$, $u = \pi(1.13\sqrt{c_1 c_2} + d)$, $c_1 \le 1.5 c_2$

E DIN 1045-1, EC 2: $u = 2(c_1 + c_2) + 3\pi d$, $c_1 \le 2c_2$

BS 8110: $u_1 = 2(c_1 + c_2) + 12d$, $u_2 = 2(c_1 + c_2) + 18d$

ACI 318, CSA A23.3: $u = 2(c_1 + c_2) + 4d$

CEB - FIP 1990: $u = 2(c_1 + c_2) + 4\pi d$

Fig. 1 Critical perimeter

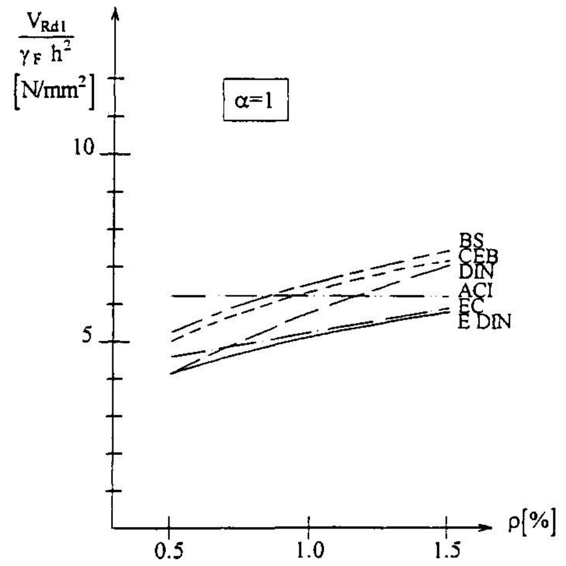


Fig. 2 Interior column: Shear resistance without shear reinforcement

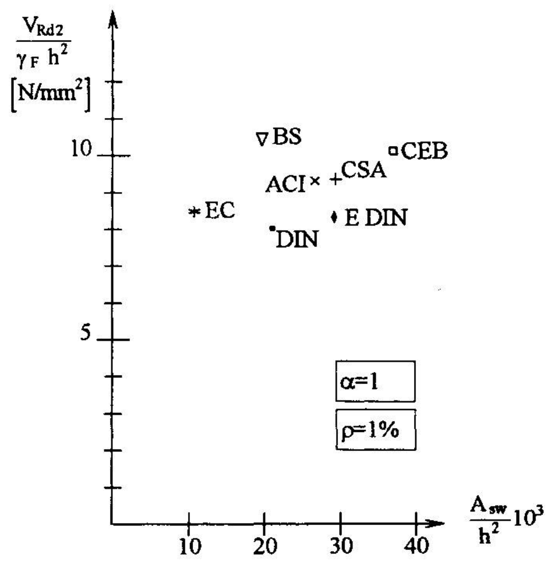


Fig. 3 Interior column: Shear reinforcement