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Efficient Embossment for Corrugated Steel Sheeting

Efficacité des bossages pour les panneaux d'acier strié

Die wirkungsvollen Prägungen für Trapezbleche

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SUMMARY
This article reports the results of experimental research of shear bond resistance of some types of embossed corrugated sheeting for composite slabs. The research consisted of pull-out model tests and full-scale one-way slab tests. It is shown the new enbossement is the most efficient for steel sheet reinforcement.

RÉSUMÉ
Cet article rapporte les résultats d'essais expérimentaux de résistance au cisaillement de quelques types de panneaux d'acier strié servant d'armature à des dalles mixtes. Cette étude a comporté des essais de rupture à la presse sur modèles réduits et des essais grandeur nature de dalles portant dans un seul sens. Ces expériences ont montré que ces nouveaux bossages ont une efficacité maximale sur le comportement de l'armature en panneaux d'acier strié.

ZUSAMMENFASSUNG
Die Ergebnisse von Versuchen zum Schub-Verbund-Widerstand mehrerer Trapezblecharten mit zusätzlichen Einprägungen werden vorgestellt. Es handelt sich dabei um Auszugversuche an Modellen und um Belastungsversuche an einfach aufgelagerten Platten. Es zeigte sich, dass die neuen Prägungsformen zu einem sehr guten Verbundverhalten führen.

I. INTRODUCTION

Efficient using of profiled steel sheeting as **reinforcement of** composite slabs depends on bond resistance between it and concrete. One of widespread modes to increase the bond resistance between slab and profiled sheeting is carrying out of local embossment on corrugations in the process of rolling. Various types of embossment for reinforced corrugated sheeting of circular or rectangular forms, of constant or variable depth etc. are known. The presented experimental research was carried out for estimation of embossment type influence on bond resistance between the reinforced profiled sheeting and concrete and on the slab strength as well. The investigation consisted of model pull-out tests and bend tests of full-scale composite slabs.

2. PULL-OUT TESTS.

Each specimen consisted of two parallel steel sheets with a monolithic concrete block casted in-between /Fig. Ia/. Displacement of this block relatively to the steel sheets fixed to a rigid frame was carried out by means of a hydraulic jack and measured with an accuracy of 0.01 mm /Fig. Ib/. The concrete compressive strength was about 23 MPa. The sheets made of galvanized steel about 1 mm thick were cleaned of dirt and oil. The bond between the concrete and the sheets was secured only at the expense of embossment of various shapes performed by cold stamping /Table I/. All embossments despite of their pattern had a constant depth 4.5 mm and the same total contact area with the concrete.

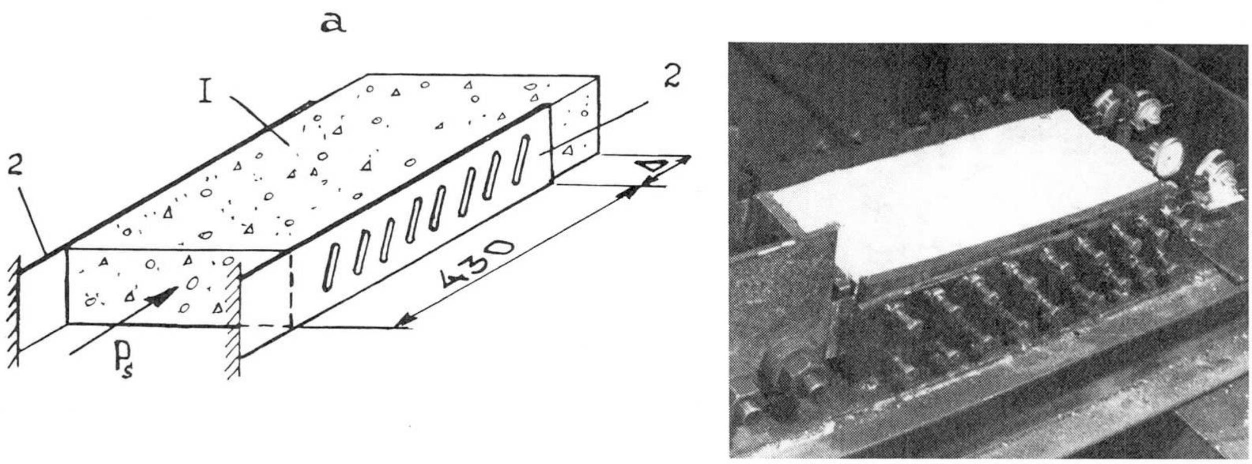


Fig.1. Arrangement (a) and general view (b) of pull-out test
I - monolithic concrete block, 2 - steel sheet.

The specimens with smooth sheets (without embossment) were considered as a base analogue to other specimens.
The results of pull-out tests consisted of load-slip relationships for mutual displacement of the concrete block and steel sheets /Fig. 2a/. Max. values of a shear load were also presented /Tab.1/.
The analysis of the failure surfaces photos after testing showed that shear forces on the contact surfaces of the specimens with

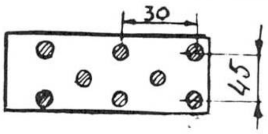
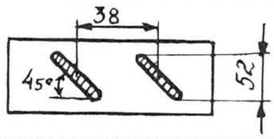
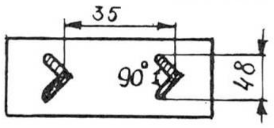
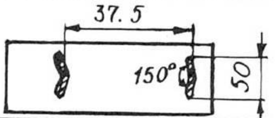
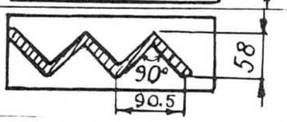
Mark of embo-ssment	Embossment pattern	Number of spe-cimens	Average shear load (kN) for slip =0.3mm	Average shear load (kN) for failure	Sheeting Fabricator
EI	without emboss-ment	3	I.9	2.5	-
E2		3	4.0	8.8	"Becker" (Germany)
E3		3	6.0	13.5	"Inland-Ryer-son" (USA)
E4		3	6.4	13.3	"Airtherm" (USA)
E5		3	8.8	14.6	TSNIIPSK (USSR)
E6		3	10.0	17.3	TSNIIPSK (USSR)

Table I. Pull-out test results.

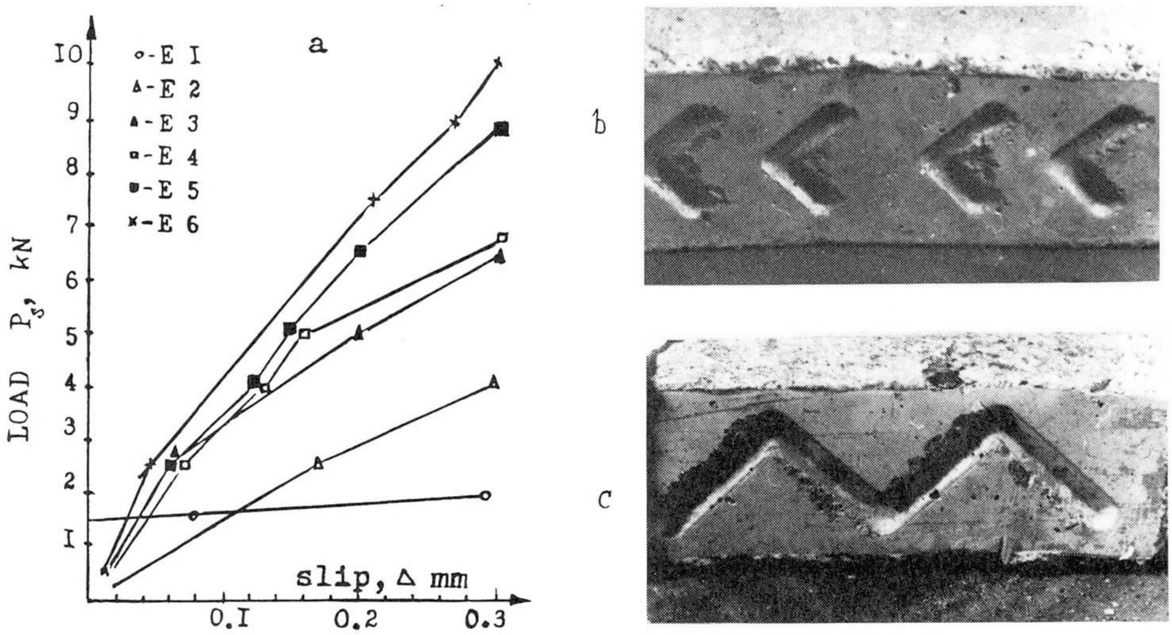


Fig.2 Load-slip relationship (a) and failure surfaces of the specimens with E4 (b) and E6 (c).

embossments E6 were distributed more uniformly than in other specimens /Fig. 2b,c/. The bond strength of the specimens E6 was higher than that for any other specimens /Tabl. I/.

3. TESTS OF COMPOSITE SLABS.

To study the efficiency of embossed profiled sheetings in real conditions full-scale transverse bending tests of 35 one-span composite slabs, reinforced with these sheets were carried out. The slabs consisted of cold-formed profiles with trapezoidal corrugations 60 or 80 mm high with wider flanges down and concrete layer over them /Fig. 3a/. The bond between the sheeting and concrete in the slabs was ensured by the embossments pressed into corrugation webs. The types of the embossments were similar to those used in the pull-out tests /Tabl. I/. The profiles were cut from standard galvanized sheets 1 mm thick with the yield strength from 260 to 320 MPa. The slabs 2.2 m long and 160 mm thick after pouring of the concrete were subjected to vibration on a shaking table and then placed into a steam heating camera for 12 hours at constant temperature 80°C. After that the measured concrete compression strength were from 21 to 30 MPa.

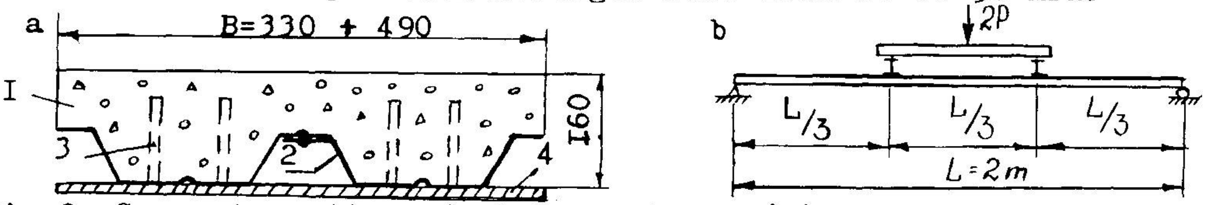


Fig.3. Support section of slab specimens (a) and test load arrangement (b) : 1 - concrete; 2 - reinforced profile; 3 - anchor studs; 4 - support plate.

Before concrete pouring the profiled sheeting was fixed to support steel plates with weld **fusion** spots or anchor studs of 14 mm diameter welded by fusion through the sheeting /Fig. 3a/. Fourteen variations of embossment types, corrugation heights and end anchorages were used for test specimens.
The slabs of 2 m span were tested on pure bending by two line loads applied to the thirds of the span /Fig. 3b/.
The loads were applied by a hydraulic jack and transmitted to the specimen by means of spreader beams. The end slip between the concrete and the profiled sheeting as well as the midspan deflection were measured at load increments /Fig. 4/.

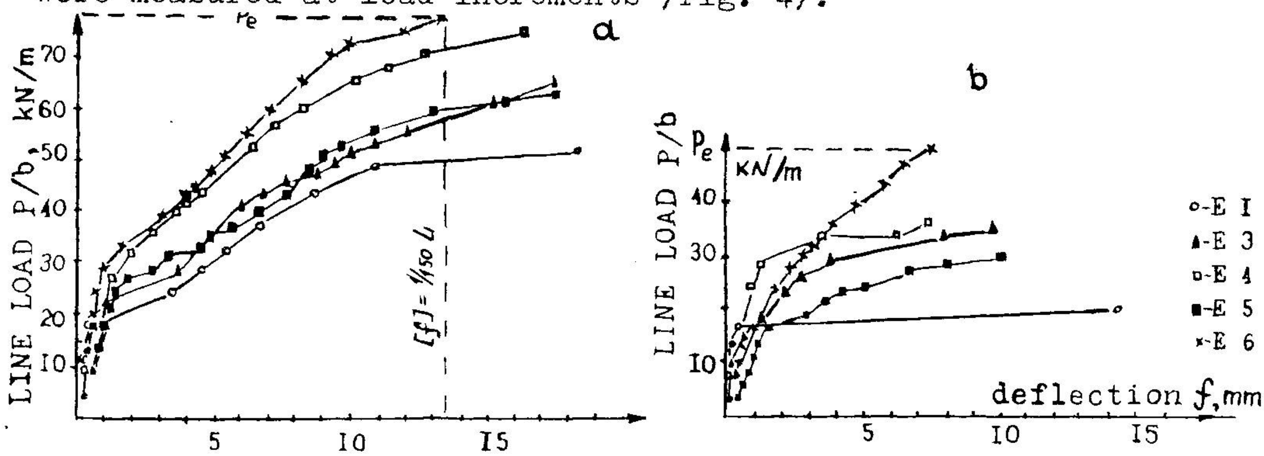


Fig. 4. Load-deflection curves for slabs with (a) and without (b) anchor studs.

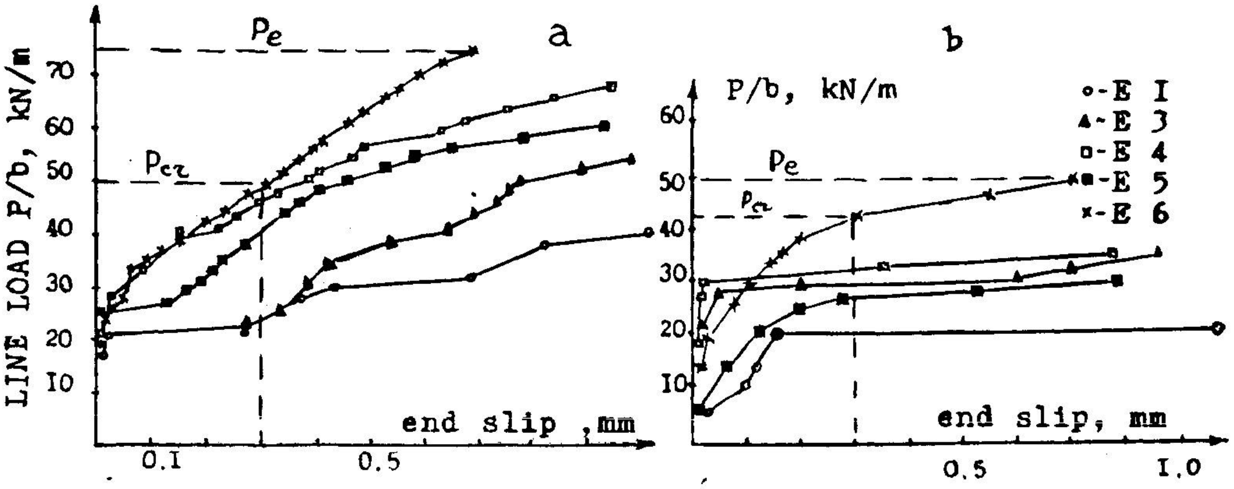


Fig. 5. Load-end slip curves for slabs with (a) and without (b) anchor studs.

First cracks formed in tensiled concrete zone near midspan were observed when end slip was about 0,3 mm. The loads P_{cr} corresponded to this slab state, compared with the specimens with different types of embossment. The largest values P_{cr} were observed for the specimens with the embossed profiles E6 /Fig. 5 /. The rigidity and the strength of these slabs were higher than that for the other specimens with /Fig. 4a/ or without /Fig. 4b/ of anchor studs.

Max. test load value P_e compared with the ultimate design load P_u was defined as

$$P_u = 6R_c X (h_o - \frac{X}{2}) \frac{B}{L}$$

where R_c is the compressive strength of concrete;

$X = \frac{Y_n F_y A_s}{R_c B}$ - the depth of the compressive zone of the slab;

F_y and A_s - the yield point and the section area of the steel profile;

h_o - the distance from the extreme compression fibre of the concrete to the neutral axis of the profile;

B and L - the width and the span of the slab;

Y_n =0.8 - the safety coefficient of the profiled sheeting. I .

The comparison of the theoretical and the test values of the limit load showed, that all the considered types of the corrugated sheeting could not completely realize the yield strength of the steel reinforcement in the composite slabs without anchor studs (the max. ratios P_e/P_u were about 0.6 for the slabs reinforced with the embossed profiles E6). An average safety coefficient of the profiled sheeting of E6-type for the slabs with the support anchors was 0.76, for the other types of the embossed profiles - Y_n = 0.61-0.72.

4. CONCLUSIONS.

Of the five embossment types of corrugated sheets tested the bond characteristics of the new embossment, marked E6 and worked out at the TSNIIPSK Institute in Moscow, were found the best. In order to increase the efficiency of corrugated sheeting with embossment in composite slabs, end anchor studs are recommended.

REFERENCE

1. Recommendations on design of monolithic reinforced concrete decks with steel corrugated sheeting. Stroyizdat, Moscow, 1987, pp. 13-15.