ISSN 2304-6295

Bearing Capacity of Reinforced Concrete T-beams with a Steel Profile

Korsun, V.I.[1]*; Vinogradova, N.A.[2]; Shvets, G.A.[3]

[1] Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia
[2] JSC “LENMORNIIPROEKT”, St. Petersburg, Russia
[3] Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
* korsun_vi@mail.ru

Key words:
Reinforced concrete; Composite steel and concrete structures; Experimental research; Deformations; Load bearing capacity

Abstract:
The object of research is a reinforced concrete T-beam element of prefabricated monolithic slabs with a thin-walled steel profile. Previously, the steel profile was used in the beams as a stay-in-place formwork, while the authors proposed to include it in the structural behaviour by anchoring. Four variants of T-beam elements have been tested to assess the influence of a thin-walled steel profile on the load-bearing capacity over normal sections. As a result, the strength capacity of reinforced concrete beams with anchored steel profile is 55% higher than the strength capacity of similar samples without steel profile.

1 Introduction

Steel-concrete structures, in which rigid steel reinforcement is combined with traditional reinforced concrete, have become widespread in construction practice and are well studied [1–3].

Numerous studies have proven the high efficiency of the external reinforcement of classic reinforced concrete, [4–6] which guarantees the combined action of concrete and steel [7–9]. As a rule, additional devices, such as special anchors or special perforated steel sheets, are used to ensure their reliable bonding [10–12]. If this condition is met, an effective complementarity of the steel profile and reinforced concrete which are the part of a complex structure is achieved. It is complicated in classical metal and reinforced concrete structures [13–24].

Reinforced concrete T-beam elements of prefabricated monolithic slabs "MARCO" with [25] thin-walled steel profile (Fig. 1a) used as stay-in-place formwork (Fig. 1b) were tested within the framework of this study. The main feature of such a construction system is the use of a thin-walled steel profile as an element of stay-in-place formwork.

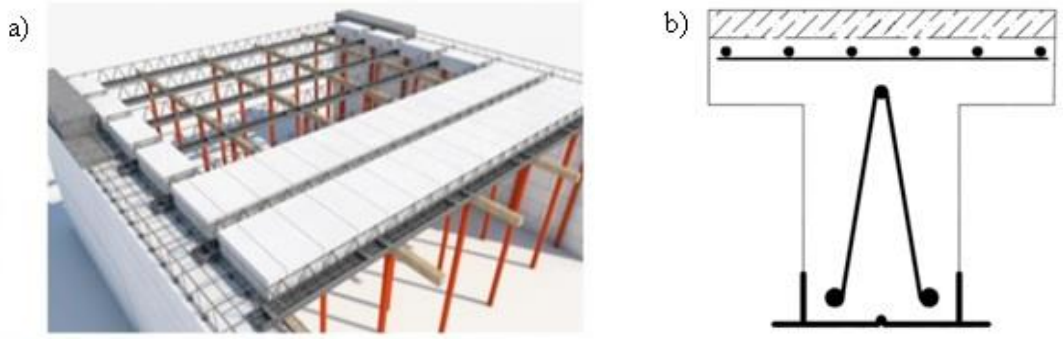

Figure 1 – Prefabricated monolithic slab: a) general view; b) cross-section of the beam element

The purpose of this study was to study the influence of the efficiency of combined action of reinforced concrete and external thin-walled sheet reinforcement as an element of stay-in-place formwork on the rigidity, crack resistance and load-bearing capacity, on the stress-strain behavior of reinforced concrete T-beam elements of prefabricated monolithic slabs, as well as to develop the recommendations for their calculation.

2 Methods

The main test samples are reinforced concrete T-beams with 120 mm rib width, 740 mm flange width, 250 mm height and 3000 mm length:

- a beam with a reinforcement cage without a thin-sheeted profile (I-I, I-II);
- a beam with a reinforcement cage and aerated concrete blocks of 600×300×200 mm, located under the overhangs of the concrete T-beam section (II);
- a beam with a reinforcement cage and a thin-walled steel profile in the lower tension region (III-I);
- a beam with a reinforcement cage, thin-walled steel profile (III-II) and additional anchoring of the profile in reinforced concrete (10 pieces on each side) (Fig. 2);
- a beam with a reinforcement cage and steel profile with aerated concrete blocks of 600×300×200 mm, located under the overhangs of the concrete T-beam section (IV). The beam was modified on site by drilling holes in concrete and installing anchors (10 pcs. in the bottom of the profile on each side, Fig. 2).

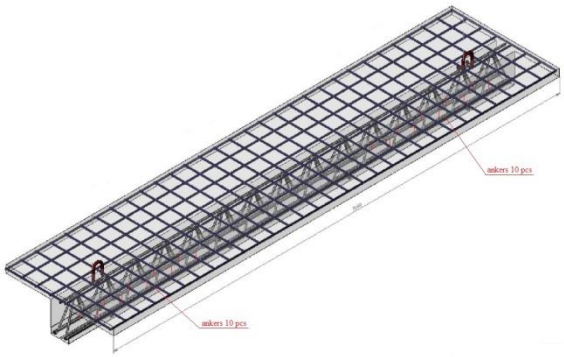

Figure 2 – Anchoring of the steel profile to the beam

The tests were conducted according to the scheme of a hinged beam with forces concentrated at the two third-points. The beam samples were completely destroyed. The sags, crack widths and applied transverse forces *Q* (Figure 3) were measured during the test.

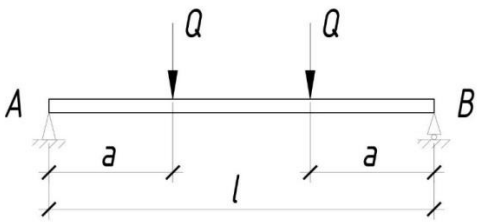

Figure 3 – Beam Testing Scheme

The experimental set-up is shown in Figure 4.

Figure 4 – Experimental set-up

The physical destruction of the samples characterized by large plastic deformations of the steel profile (beam III-I) and the destruction of the rib in the region of pure bending (others) was taken as the limit state.

3 Results and discussion

The results of the experiment are presented as graphs of the dependence of sample sag values on bending moments (Fig. 5). Samples with a steel profile and no special anchorage have a load-bearing capacity which is 15% higher than a load-bearing capacity of those without a profile, and samples with a steel profile that is securely anchored with the special steel screw plugs have a load-bearing capacity which is 55% higher.

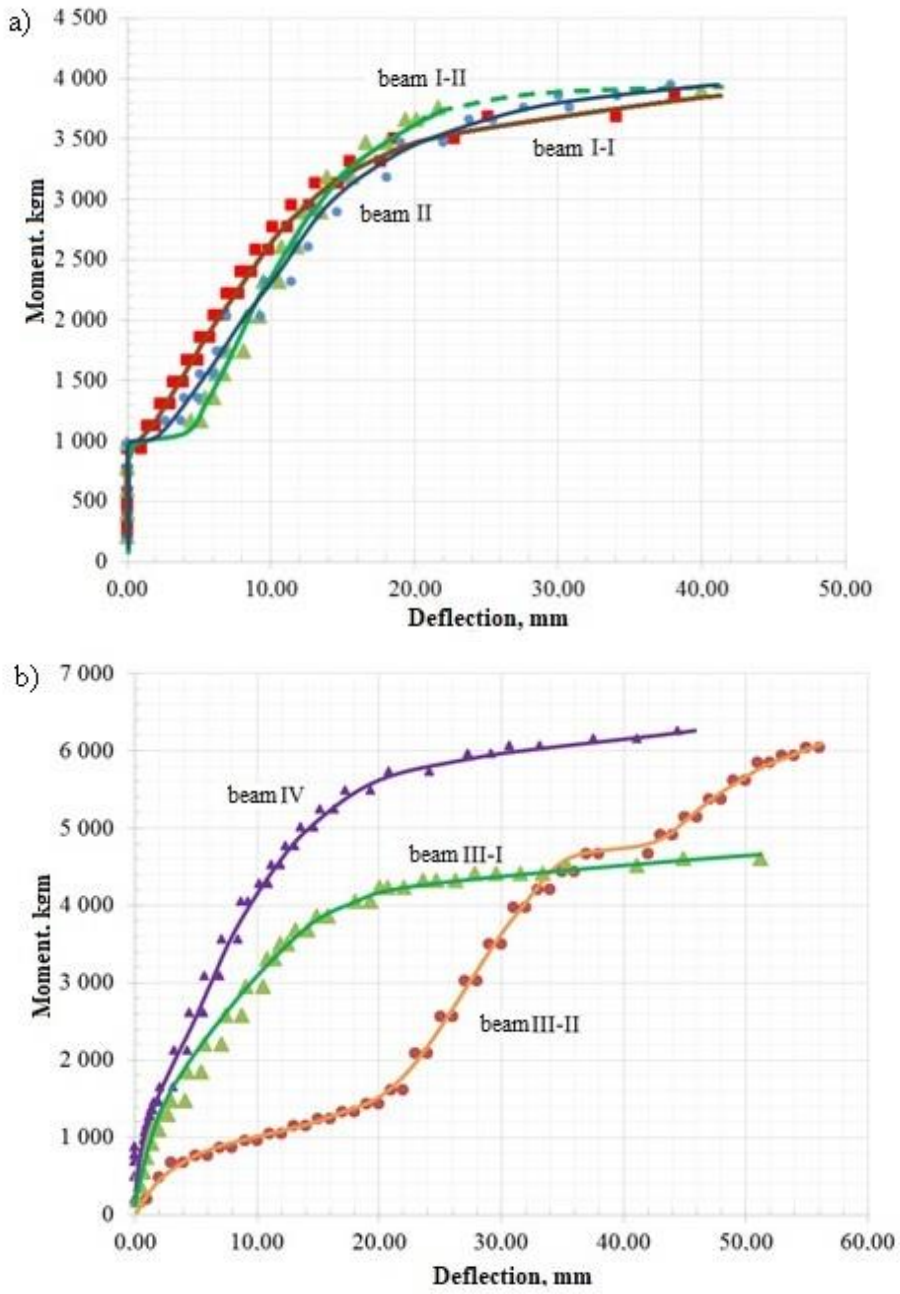

Figure 5 – *M-Sag* graphs for beams: a) I-I, I-II, II; b) III-I, III-II, IV

Results of beams load-bearing capacity calculations conducted according to the method of SP (Russian Construction Rules) 63.13330.2012 "Concrete and reinforced concrete structures. General provisions" and their comparisons with experimental data are presented in Table 1.

Table 1 – Measured and calculated values of beams load-bearing capacity

Beam Test Samples					
Beam I-I	Beam I-II	Beam II	Beam III-I	Beam III-II	Beam IV
Calculated value					
26.2 65.2%	26.2 65.2%	25.2 62.5%	47.2 117.5%	43.1 107.0%	43.6 108.5%
Test data					
40.0 99.5%	40.4 100.5%	40.2 100.0%	46.2 115.7%	61.2 155.0%	63.3 160.0%

Notes:

1. Above the line are the values of bending moments M (kN*m), under the line are the relative values (%);
2. The bending moment calculated as the arithmetic mean of the values of moments obtained for I-I and I-II samples is taken for 100%.

4 Conclusions

The test results showed that the use of thin steel profiles in the lower (tension) region of load-bearing beams of prefabricated monolithic slabs without special anchoring devices increases their load-bearing capacity by about 15%. If the profile is fixed using special anchoring devices, the increase in load-bearing capacity reaches about 55% in comparison with beams without a profile. This indicates the effective influence of external reinforcement on increasing the load-bearing capacity and rigidity of reinforced concrete bending elements.

According to the method of SP (Russian Construction Rules) 63.13330.2012 "Concrete and reinforced concrete structures. General provisions", the calculation of the load-bearing capacity of bending reinforced concrete beams with thin-walled profile in the tension region requires the introduction of a correction factor to the design resistance of steel to take into account the effectiveness of the bond between the profile sheets and concrete.

The method of anchoring the sheet profile as a stay-in-place formwork element has a decisive influence on the compatibility of the external reinforcement and the reinforced concrete beam.

Further studies are aimed at the development of an effective (in terms of combined action) and technologically advanced method of anchoring a thin-walled steel profile in concrete, as well as at the justification of the reliability of an engineering method for calculating structures of this type.

References

1. Rybakov, V.A., Kozinetc, K.G., Vatin, N.I., Velichkin, V.Z., Korsun, V.I. Lightweight steel concrete structures technology with foam fiber-cement sheets. Magazine of Civil Engineering. 2018. 82(6). Pp. 103–111. DOI:10.18720/MCE.82.10. URL: http://engstroy.spbstu.ru/index_2018_06/10.pdf.

2. Travush, V.I., Konin, D. V, Krylov, A.S. Strength of composite steel and concrete beams of high-performance concrete. Magazine of Civil Engineering. 2018. 79(3). Pp. 36–44. DOI:10.18720/MCE.79.4. URL: http://engstroy.spbstu.ru/index_2018_03/04.pdf.

3. Medvedev, V.N., Semeniuk, S.D. Durability and deformability of braced bending elements with external sheet reinforcement. Magazine of Civil Engineering. 2016. 63(03). Pp. 3–15. DOI:10.5862/MCE.63.1. URL: http://www.engstroy.spbstu.ru/index_2016_03/01.html.

4. Holomek, J., Bajera, M., Vilda, M. Test Arrangement of Small-scale Shear Tests of Composite Slabs. Procedia Engineering. 2016. 161. Pp. 716–721. DOI:10.1016/J.PROENG.2016.08.749. URL: https://www.sciencedirect.com/science/article/pii/S1877705816329782.

5. Derysz, J., Lewiński, P.M., Więch, P.P. New Concept of Composite Steel-reinforced Concrete Floor Slab in the Light of Computational Model and Experimental Research. Procedia Engineering. 2017. 193. Pp. 168–175. DOI:10.1016/J.PROENG.2017.06.200. URL: https://www.sciencedirect.com/science/article/pii/S1877705817327480.

6. Zamaliev, F.S., Zakirov, M.A. Stress-strain state of a steel-reinforced concrete slab under long-term. Magazine of Civil Engineering. 2018. 83(7). Pp. 12–23. DOI:10.18720/MCE.83.2. URL: http://engstroy.spbstu.ru/index_2018_07/02.pdf.

7. Braila, N. V, Khazieva, K.L., Staritcyna, A.A. Results of technical inspection monitoring of the operation object. Magazine of Civil Engineering. 2017. 74(6). Pp. 70–77. DOI:10.18720/MCE.74.7. URL: http://engstroy.spbstu.ru/index_2017_06/07.pdf.

8. Rybakov, V.A., Ananeva, I.A., Rodicheva, A.O., Ogidan, O.T. Stress-strain state of composite reinforced concrete slab elements under fire activity. Magazine of Civil Engineering. 2017. 74(6). Pp. 161–174. DOI:10.18720/MCE.74.13. URL: http://engstroy.spbstu.ru/index_2017_06/13.pdf.

9. Koyankin, A.A., Mitasov, V.M. Stress-strain state of precast and cast-in place buildings. Magazine of Civil Engineering. 2017. 74(6). Pp. 175–184. DOI:10.18720/MCE.74.14. URL: http://engstroy.spbstu.ru/index_2017_06/14.pdf.

10. Korotchenko, I.A., Ivanov, E.N., Manovitsky, S.S., Borisova, V.A., Semenov, K. V, Barabanshchikov, Y.G. Deformation of concrete creep in the thermal stress state calculation of massive concrete and reinforced concrete structures. Magazine of Civil Engineering. 2017. 69(1). Pp. 56–63. DOI:10.18720/MCE.69.5. URL: http://engstroy.spbstu.ru/index_2017_01/05.pdf.

11. Krivtcov, A., Gravit, M., Zimin, S., Nedryshkin, O., Pershakov, V. Calculation of Limits of Fire Resistance for Structures with Fire Retardant Coating. MATEC Web of Conferences. 2016. 53. Pp. 01032. DOI:10.1051/matecconf/20165301032. URL: http://www.matec-conferences.org/10.1051/matecconf/20165301032.

12. Smirnova, O.M. Compatibility of portland cement and polycarboxylate-based superplasticizers in high-strength concrete for precast constructions. Magazine of Civil Engineering. 2016. 66(6). Pp. 12–22. DOI:10.5862/MCE.66.2. URL: http://engstroy.spbstu.ru/index_2016_06/02.pdf.

13. Snigireva, V.A., Gorynin, G.L. The nonlinear stress-strain state of the concrete-filled steel tube structures. Magazine of Civil Engineering. 2018. 83(7). Pp. 73–82. DOI:10.18720/MCE.83.7. URL: http://engstroy.spbstu.ru/index_2018_07/07.pdf.

14. Travush, V.I., Krylov, S.B., Konin, D. V, Krylov, A.S. Ultimate state of the support zone of reinforced concrete beams. Magazine of Civil Engineering. 2018. 83(7). Pp. 165–174. DOI:10.18720/MCE.83.15. URL: http://engstroy.spbstu.ru/index_2018_07/15.pdf.

15. Alekseenko, V.N., Zhilenko, O.B., Al Ali, M. Bearing capacity of pasted anchors in the masonry walls of natural limestone. Magazine of Civil Engineering. 2018. 81(5). Pp. 52–63. DOI:10.18720/MCE.81.6. URL: http://engstroy.spbstu.ru/index_2018_05/06.pdf.

16. Lushnikova, V.Y., Tamrazyan, A.G. The effect of reinforcement corrosion on the adhesion between reinforcement and concrete. Magazine of Civil Engineering. 2018. 80(4). Pp. 128–137. DOI:10.18720/MCE.80.12. URL: http://engstroy.spbstu.ru/index_2018_04/12.pdf.

17. Ahmed, I.M., Tsavdaridis, K.D. The evolution of composite flooring systems: applications, testing, modelling and eurocode design approaches. Journal of Constructional Steel Research. 2019. 155. Pp. 286–300. DOI:10.1016/J.JCSR.2019.01.007. URL: https://www.sciencedirect.com/science/article/pii/S0143974X18307296.

18. Szumigała, M., Polus, Ł. An Numerical Simulation of an Aluminium-concrete Beam. Procedia Engineering. 2017. 172. Pp. 1086–1092. DOI:10.1016/J.PROENG.2017.02.167. URL: https://www.sciencedirect.com/science/article/pii/S1877705817306732.

19. Ataei, A., Bradford, M.A., Valipour, H. Sustainable Design of Deconstructable Steel-Concrete Composite Structures. Procedia Engineering. 2016. 145. Pp. 1153–1160. DOI:10.1016/J.PROENG.2016.04.149. URL: https://www.sciencedirect.com/science/article/pii/S1877705816301564.

20. Gholamhoseini, A., Gilbert, R.I., Bradford, M.A., Chang, Z.T. Long-term deformation of composite concrete slabs under sustained loading. From Materials to Structures: Advancement Through Innovation - Proceedings of the 22nd Australasian Conference on the Mechanics of Structures and Materials, ACMSM 2012. 2013. Pp. 67–72. DOI:10.1201/b15320-12.

21. Gholamhoseini, A., Gilbert, R.I., Bradford, M.A. Creep and Shrinkage Effects on the Bond-Slip Characteristics and Ultimate Strength of Composite Slabs. Journal of Civil Engineering and Architecture. 2014. 82. Pp. 1085–1097. DOI:10.17265/1934-7359/2014.09.001.

22. Gholamhoseini, A., Gilbert, R.I., Bradford, M. Long-term behavior of continuous composite concrete slabs with steel decking. ACI Structural Journal. 2018. 115(2). Pp. 439–449. DOI:10.14359/51701133.

23. Baniya, W.J., Zaki, W., Farrag, C.M.R., Rashed, D.A. Behavior of composite pre-flat slabs in resisting punching shear forces. Alexandria Engineering Journal. 2020. 59(1). Pp. 333–347. DOI:10.1016/j.aej.2019.12.045.

24. Holomek, J., Bajer, M., Vild, M. Cast Screws as Shear Anchors for Composite Slabs. Procedia Engineering. 2017. 195. Pp. 114–119. DOI:10.1016/j.proeng.2017.04.532.

25. Gravit, M., Nedviga, E., Vinogradova, N., Teplova, Z. Fire resistance of prefabricated monolithic slab. MATEC Web of Conferences. 2017. 106. Pp. 02025. DOI:10.1051/matecconf/201710602025. URL: http://www.matec-conferences.org/10.1051/matecconf/201710602025.