New building technology for prestressed concrete structures

New Building Technology for Prestressed Concrete Structures

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Summary

The new building technology offered has led us to the possibility of increasing concrete strength in prestressed structures up to 50- 70 per cent, crack resistance being usual. It is achieved due to compressing unset concrete mix during the operation of steel tensioning. A wide range of research and practical studies has shown that the given technology provides necessary steel pretensioning and uniform or predetermined concrete compaction as well as hardening of concrete in a structure.

1. Introduction

Prestressed concrete structures are usually produced according to post-or pretensioning technology [1]. There are a great number of proposals as to the realization of these technologies. The majority of them are well studied, and some of the best ones find their practical application. Almost all these suggestions can be united according to the principle of the steel prestressing transfer, namely onto the hardened strong concrete. The possibilities of manufacturing more effective prestressed reinforced concrete structures in the limited frames of the single principle are in many respects exhausted. Many specialists think it is the reason for slowing down progress in this direction. We need here qualitative transition to new concepts in the sphere of prestressed concrete to have precedents for rapid flourishing of ideas and developments.

2. New technology

The author has offered and put into practice the principle of prestressing transfer onto the freshly placed concrete mix of structures. In this case prestressing is made already at the stage of cement concrete components.

After vibrodynamic compaction, the placed unset mix is under compression of the steel prestressing force, and it hardens under the pressure. All this leads to the concrete mix compaction, the removal of water excess and air from the mix, to eliminating macro- and partly microdefects of the concrete structure, and to restraining destructive processes during concrete hardening. Steel prestressing is preserved, for after the compaction of the specially proportioned concrete mix, rather a strong and rigid skeleton of solid ingredients is formed, and the stressed steel is then fixed onto this skeleton (fig. 1).

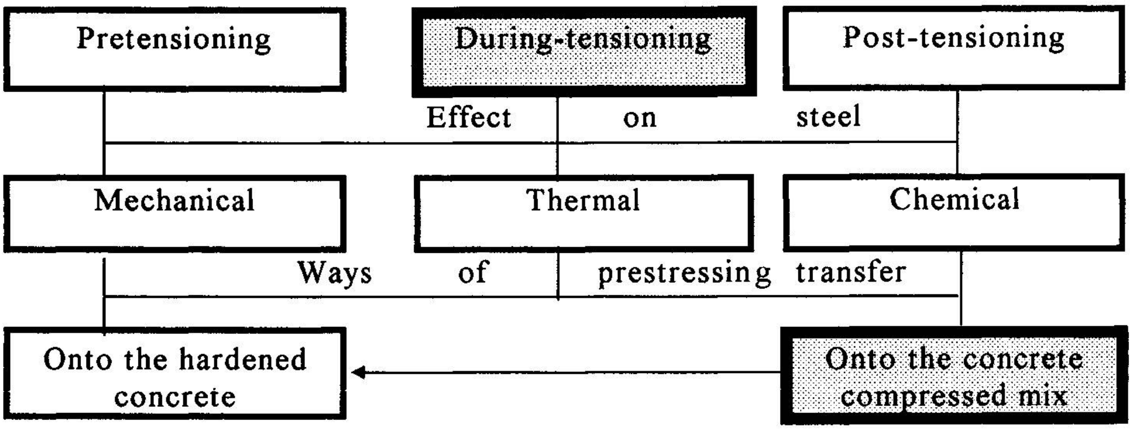


Fig. 1. Extended scheme of methods of making prestressing in reinforced concrete structures

It is also possible to partially transfer steel prestressing onto the concrete mix [2]. The realization of the new technology method of concrete mix prestressing became possible after the author had invented original movable forms and devices for full or partial prestress transfer [3].

Considerable increase of the effect of uniform concrete compression, the elimination of undesirable initial stress in reinforcement is possible due to the application of movable steel bars proposed by the author. The bars are made in a special way. During the pretension these elements are shortened within the length of the structure. The concrete contacting the steel is compressed and reaches a high degree of compaction. A high quality contact is provided. Prestressing is transferred onto the concrete.

3. Experimental results

According to the offered presstressing method there have been made experimental beams with rectangular cross section and dimensions of 100x200x2000mm and columns with round cross section (d=250 and l=1500mm). Under comparison in all equal conditions traditional prestressed elements and usual reinforced concrete ones were also produced. The results of beam and column tests are graphically presented on fig. 2.

For the experimental beams with μ=2.2 per cent we have reached the increase of carrying capacity up to 25-34 per cent due to the compression according to the new method. The effect of carrying capacity increase in columns amounted to 75 per cent. It is illustrated graphically on fig.3, where K is the ratio of the carrying capacity of a reinforced concrete element compressed according to the "during-tensioning" method to the usual one.

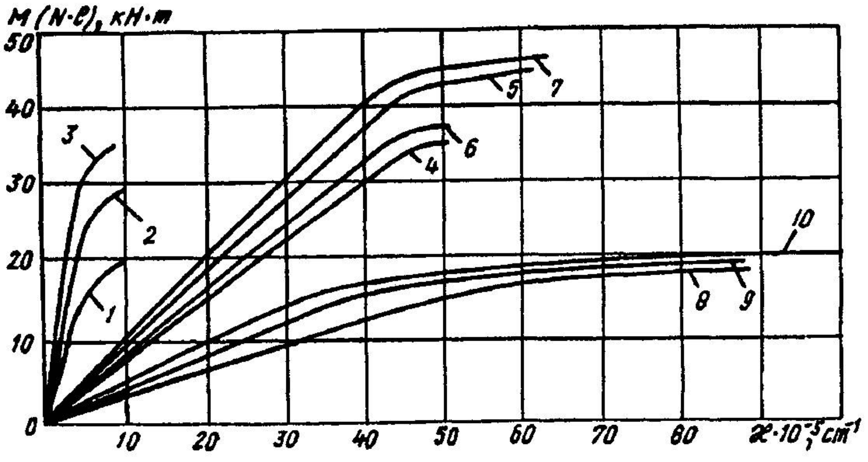
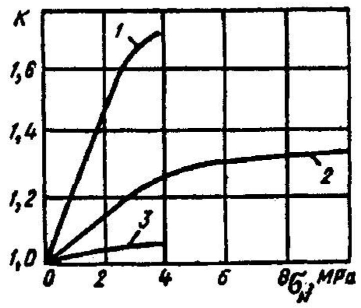


Fig. 2. Typical relationship "load-curvature"

1; 2 and 3 – for the columns with σ_N correspondingly 0; 2 and 4 MPa;
4; 5; 7 – for the beams with μ=2.2% when σ_N is correspondingly 0; 5; 10 MPa, and
6 – according to the "pretensioning" method;
8; 9 and 10 – for the beams with μ=0.063, when σ_N is correspondingly 0; 2 and 4 MPa.

The analysis of the results shows that the losses of steel prestressing caused by the deformations of the compressed mix, shrinkage and concrete creep are less than in traditional structures. The prism strength of concrete after the compression increased up to 2.2 times comparing it with the initial one. The most



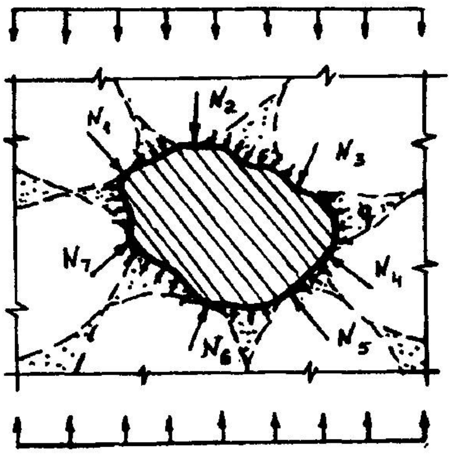
1- for columns;
2- for the beams with μ=2.2%;
3- for the beams with μ=0.6%.

Fig. 3 Diagram "K- σ_N"

intensive strength growth was marked under the pressure value up to 6 MPa. The values of elasticity modulus E_b and relative deformations ε_{bR} increased by 40-50 per cent.

4. Theoretical analysis

According to the research data obtained by the author, to preserve the force of steel prestressing we should use in the offered structures concrete with contacting skeleton location of the grains of strong coarse aggregate after compaction. In addition, the greater part of the prestressing force is transferred contactingly through thin mortar membranes in a grain-to-grain way (fig. 4.).



To get a strength formula for prestressed reinforced concrete of a matrix-carcass structure the author has suggested that one should proceed (besides the well-known premises) from the fact that the value of failure loading depends on the crushability of grain mix of coarse aggregate as integral characteristics of its strength. The influence of precompression and dynamic effect on the concrete mix is revealed in compaction, and also in additional loading of the skeleton of coarse aggregate grains.

Fig. 4. Scheme of loading of coarse aggregate grain

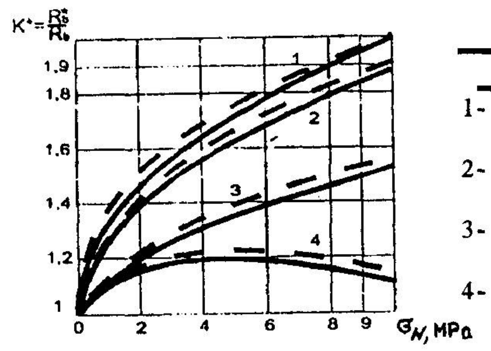
Taking into account the above mentioned and proceeding from the well-known premises, there has been obtained the following formula of strength of prestressed concrete with a matrix-carcass structure:

$$R_B^* = \left(K_P \frac{q}{K_c} + K_1 K_2 K_3 (1+\alpha_1 \ln 9.8p) R_{mbt} - c\sigma_N \right) \cdot \left(\frac{1}{1-(1+\alpha_2 \ln 9.8p)\frac{E_m}{E_{ag}}} - K_V \frac{V_m}{V_b} \right)$$

Here K_p – index reflecting the change of structure composed of coarse aggregate under crushability (0.2-0.36); q – value of standard loading while defining the crushability of coarse aggregate grains (11.32 MPa); K_c – crushability index of coarse aggregate grains placed as in concrete, i.e. it may be filling, vibrocompaction, dynamic effect with loading; K_1, K_2 and K_3 – correspondent indices of form (1.27-1.55), relief (1.18-1.40) and microrelief (1-1.41) of aggregate grains; p – value of pressure action on the cement-sand mortar; R_{mbt} – tensile strength of the usual uncompressed mortar; $c\sigma_N$ – value of pressure acting on the coarse aggregate; E_m and E_{ag} – elastisity modulus of mortar (matrix) and aggregate material; K_V – compaction index of the mortar.

According to the given formula it is possible to calculate concrete strength under full or partial transfer of the prestressing σ_N on the concrete mix. If the prestressing is relieved after compaction, and it doesn't further load the skeleton of coarse aggregate, the value C is to equate with O. Besides, in this formula the value of the P parametre for the usual uncompressed concrete with skeleton arrangement of coarse aggregate grains equals O.

On fig.5 there are typical plots showing dependence of the index of concrete strength increase on the value of prestressing and the mode of its application. The comparison of analysis dependences with experiments testifies to their being in



——— - experimental
- - - - - - - theoretical
1- compressed under dynamic influence and its further relieving;
2- the same operation, under preserving the stress of compression;
3- compression without dynamic influence with its further relieving;
4- the same operation, under preserving the stress of precompression.

Fig.5. Diagram "K-σ_N"

agreement. The given formula shows satisfactory results in practical application. It takes into account the transfer of prestressing onto concrete mix both in cases of its preserving and relieving.

5. Production implementation

The level of research includes production implementation. At present, large 30-ton bridge elements of prestressed concrete made by compressing the unset concrete mix by the force of steel tensioning are successfully used in Ukraine (fig. 6).

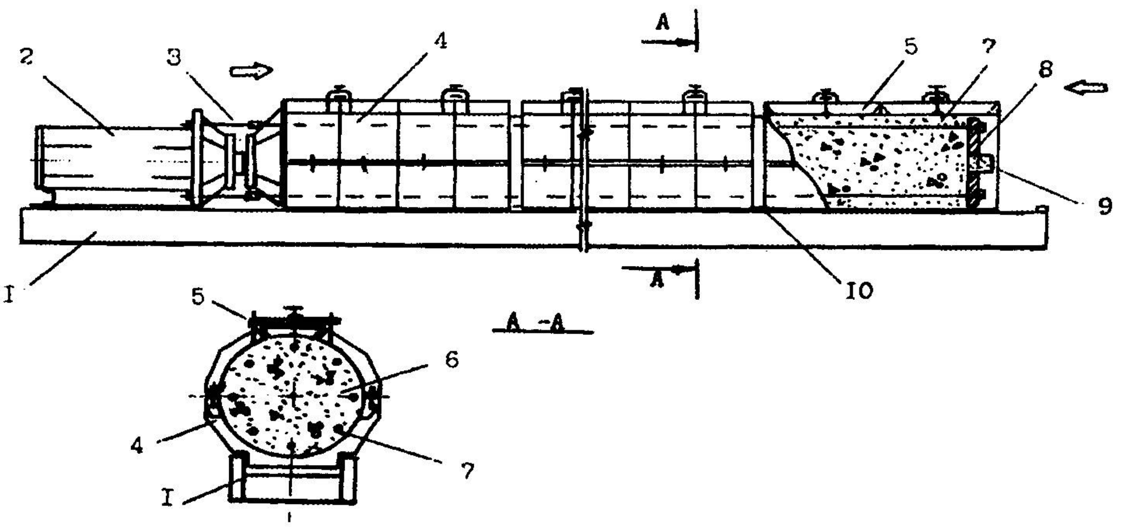


Fig. 6. Scheme of compressing the pillar in the formwork according to the " during- tensioning" method.

1- frame; 2 - tensioning device; 3 - tie-rods; 4 - section formwork; 5 - hole with screw lock; 6 - concrete mix; 7 - bar reinforcement; 8 - movable end: 9 - device for taking concrete samples; 10 - functional joint

Favouring practical application of the above mentioned elements was the device invented by the author, which provides reliable control over the quality of the compressed concrete directly in the product [3]. Service observations of the reinforced concrete pillars produced according to the technology offered in the piers of the trestle part of a large bridge over the river Dnieper in the town Dneprodzerzhinsk (Ukraine) confirmed high quality of the structures compressed according to the "during-tensioning" method.

6. Conclusions

Taking as a basis the experimental research data, we can state that self-organization of concrete structure at the stage of mix prestressing, concrete density, high bond between concrete and steel, preservation of the force of prestressing - all this becomes a guarantee for high strength and quality of the concrete elements offered. Industrial application of prefabricated bridge elements with prestressing onto the concrete mix has proved the expediency of the method proposed.

The current level of the method development allows recommending for the lot production the following reinforced concrete structures: columns and pillars, piers, bulky foundation elements, some beams, thick slabs for briges, airfields and motorroads, curbstones, tram and train ties, poles.

We expect that further experimental research and perfection of the "during-tensioning" method will make it possible to broaden the list of economically expedient compressed reinforced structures, the lot production of the ones compressed according to the new method, and tested in practice, hopefully favouring progress in construction.

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