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**Autor:** Berg, O. / Karpinsky, V. / Palagin, E.

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# Compressed Reinforced Concrete Elements with Spiral Reinforcement and Their Use in the Structures

Eléments comprimés en béton avec des armatures précontraintes en spirale et l'utilisation de ces éléments en constructions

Gedrückte Stahlbetonbauteile mit vorgespannter Spiralbewehrung und ihre Anwendung in den Konstruktionen

O. BERG V. KARPINSKY

E. PALAGIN
Scientific Research Institute on Transport Construction, Moscow

The elements of long span bridges, the columns of underground stations usually carry heavy loads amounting to 2000-5000 tons. For the purpose of using in such cases sufficiently light and transportable prefabricated units, especially by underground building, The Scientific Research Institute on Transport Construction in Moscow has carried out the researches to investigate rational constructive shapes of column sections prestressed with spiral reinforcement, the strength and deformation properties of this columns as well as the methods of protective covering of reinforcement. Some results of the laboratory researches of such columns were given in the article of S.W.Brykin,published in the "Final report" of The Sixth Congress of the Association ( Stockholm,1960). The results of these researches dealt with the strength and the deformation of axially compressed solid concrete cylinders prestressed with spiral reinforcement. At present there are the results of the researches concerning the destruction features of the above mentioned reinforced concrete elements operating under eccentrical loading conditions. As core of this element use was made of hollow cylinders. Carried out furthermore were tests of real-size columns performed before using them in one of the underground stations constructed in Tbilisi, capital of Georgia. The work directed at using such elements in bridge structures is being carried out as well.

The experimental reinforced concrete columns had the following sizes: height(h) equal to 4.8 m, external diameter(d=2r) of the precast concrete core-pipe equal to 63 cm, external diameter of the column with the protective covering of the spiral reinforcement equal to 66 cm. The column core was made of the centrifuged concrete pipe with the internal diameter equal to 33 cm. The strength of the concrete was 600 kg/cm$^2$. The design of column for the underground station is given in Fig.1.

The reinforcing cage of the column consists of 24 longitudinal effective bars, diameter 20 mm, made of steel grade 30ХГ2С and auxiliary 6-mm wire reinforcement made of Ст.3 steel,with a pitch of 100 mm in the middle part of the column and 50 mm at its ends.

The column spiral reinforcement is made of 4-mm high-strength wire wound with a pitch of 7.5 mm. The ultimate strength of wire is 18000 kg/cm$^2$, the ultimate lateral pressure of wire on concrete reaches 100 kg/cm$^2$. The wire was wound round the core by means of a special machine. This machine permits winding several spirals independently. The design of the machine excludes the torque and bending moment. Wound on the core of the experimental columns were two spirals - one with a pitch of 15 mm and the other between the spires of the first spiral. The required pretension of wire equalling 12200 kg/cm$^2$ was created with a load of the preset weight. The expenditure of wire amounted to 25 kg per one metre of the column.

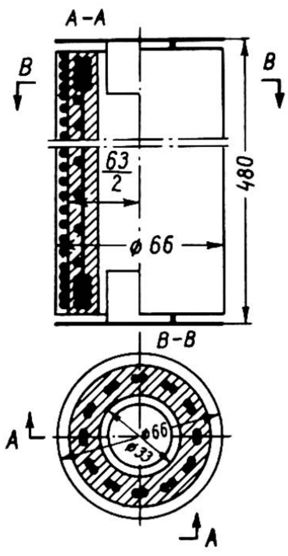


Fig.1

The results of the laboratory tests of the cylinders, h=60 cm, d=15 cm, were taken into account in the project of the experimental columns. These tests made it possible to obtain some specific information about the physical nature of spiral reinforced concrete properties.

The volumetrical deformation analysis of concrete core under load made it possible to outline the boundaries of concrete microdestruction and the upper conventional boundary of microcracks by using the methods worked out in the Institute laboratory. The experiments have testified that the beginning of concrete destruction in the unit core is connected with the development of microcracks oriented along the effective compressive load. Step by step these microdestructions turn into macrodestructions and lead to the disturbance of material continuity and to the loss of carrying capacity. At this moment a rupture of prestressed spiral reinforcement takes place. The boundary of microdestructions ($R^o{}_t$) in the specimens under test ranges from 0.35 to 0.55 $R_m$ (fig.2), where $R_m$ is the concrete maximum crushing strength. The upper conventional boundary of microcracks ($R_t$) corresponds to a load of 0.8-0.9 $R_m$. Application of a load corresponding to the boundary of microcracks in concrete results in appearing the first signs of material disconsolidation, which can be revealed with the aid of ultrasonics instruments. When compressed at the level of the upper conventional boundary of microcracks expansion of the specimen volume in-

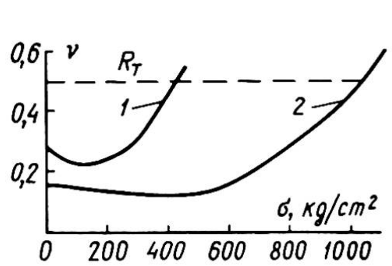


Fig.2

Relation between coefficient of lateral deformation ($\nu$) and stresses ($\sigma$) for ordinary (1) and spiral reinforced concrete(2).

stead of its contraction (as it is the case at smaller loads) takes place.

The modulus of longitudinal deformations for concrete with spiral reinforcement is slightly higher than that of ordinary concrete (without spiral reinforcement). Within the limits of working stresses this increment amounts to about 15%. The experiments have shown that the columns with prestressed spiral reinforcement are effective to resist both an axial loading and an eccentrical loading characterized by small eccentricity ($e_o$). The load eccentricity must not exceed the dimensions of kern of section. The decreasing regularity of element carrying capacity at the expence of the eccentrical application of load is similar to that found for ordinary concrete (Fig. 3). With the load applied to the boundary of kern of section the strength decrease of element having spiral reinforcement is about 25% as compared to the strength characterized by the application of axial load.

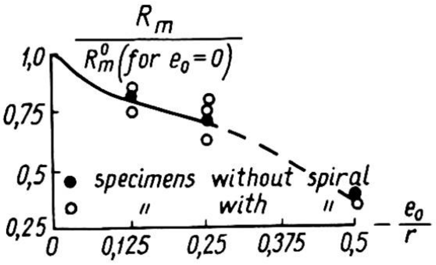


Fig. 3

Decreasing of carrying capacity depending on the relative eccentricity of pressure load

When reinforcing the spiral reinforced elements with longitudinal bars it is necessary to ensure local stability at the latter. The buckling of bars can cause the premature rupture of the spiral. As a core of the columns reinforced with spirals use may be made of centrifuged hollow pipes. In this case to estimate the concrete strength it is necessary to test tubular elements with identical cross-section instead of ordinary prisms since the production process of these elements effects their strength.

The values measured as well as direction of concrete lateral inside strains have testified that these strains are directed to the external surface of the specimen. The value of these strains is identical to the strains of the external surface of specimen. No internal strains that might cause the concrete premature failure, were observed. As a result, the concrete carrying capacity or effectiveness of spiral reinforcing have not been reduced.

The chippings in the internal surface can take place in thin-walled specimens only as a result of loss of local wall stability. The above-mentioned results relating to the tube-specimens were obtained in the cases when the wall thickness exceeded one half of the external radius of specimen. Therefore concrete pipes may be used as a core for winding prestressed spiral reinforcement if the sizes of internal and external diameters correspond to the ratio mentioned above.

Protection of spiral reinforcement against corrosion and accidental damages can be performed through the use of one of the following coatings:

a) resin-concrete coating based on epoxy resin with granite crumb or clean-rock or river sand used as aggregate material.

b) asbestos-cement thin-walled pipe to be fitted on the spiral reinforced core. In this case the free place between the pipe and the core is filled with cement mortar.

c) reinforced precast or in situ concreted thin-walled shell to be inserted into the structure after applying the dead load to the core.

For protecting coatings based on epoxy resine use were made of resins, grade ЭД-5 or ЭД-6, whose rupture strength after hardening without filler ranged from 100 to 300 kg/cm$^2$ and with cement filler from 80 to 100 kg/cm$^2$. Initially 2 or 3 layers of anticorrosive coatings film (without filler) were applied with spraying gun and then after polymerization of the first layers a protecting layer of 8 to 10 mm thick was applied. Introduction of filler decreases the elasticity of protective films but in all cases the value of the least elongation of films is several times as large as the concrete elongation value.

The results of coatings tests for salt, water- and atmospheric resistance has proved the high durability of protective coatings. Testing of coatings for continuity for the gas penetrability also confirmed their high quality.

All types of protective coatings can be carried out under conditions of a factory producing reinforced concrete elements.

Comparison of concrete elements reinforced with prestressed spirals with ordinary reinforced concrete elements shows the advantage of the former. This advantage is expressed in economy of concrete (40-50%) and metal (35-40%). Cutting of production costs amounts to 10-15%.

The experimental columns have been tested with axial compression to complete failure. The failure load of each column was about 1960 tons. The reference concrete core (without spiral reinforcement) has been broken at a load of 850 tons. The nature of failure of reinforced with spiral columns was brittle. Broken down in the zone of failure were some spiral spires. The protective coatings have broken down only in zone of spiral rupture and of concrete core failure. No breakdowns were observed in other places of columns. No internal concrete chippings of the core and bending of longitudinal bars were also observed. The maximum relative longitudinal strain, as measured on the column surface, amounted to 7 x $10^{-3}$.

The column is designed for the specified load equal to 1250 tons to be gained in a few years as measured from the moment of applying the load to the column.

## SUMMARY

The paper covers the results of the new investigations to study the carrying capacity and the physical nature of failure of axially and eccentrically loaded solid and hollow concrete columns prestressed with spiral reinforcement. Data relating to the experiments of various protective coverings of spiral reinforcement are also given. The paper also reports about the first use of spiral reinforced concrete column in underground constructions in the USSR.

RÉSUMÉ

Le travail traite les résultats des nouvelles recherches sur la résistance et la destructibilité des colonnes massives et creuses en béton armé travaillant à compression axiale et excentrique et précontraintes par des armatures en spirale, ainsi que les résultats des recherches sur les revètements protectifs de différents types des armatures en spirale. L'utilisation expérimentale des colonnes armées spéciales dans la construction du métropolitain en l'URSS est aussi reflètée dans le traité.

ZUSAMMENFASSUNG

In der Arbeit werden Ergebnisse der neuen Untersuchungen auf dem Gebiet der Tragfähigkeit und des Bruchprozesses der axial und exzentrisch gedrückten spiralbewehrten massiven und hohlen Kolonnen beschrieben. Außerdem werden Ergebnisse der Untersuchungen verschiedener Bewehrungsschutzüberzügen angeführt. In der Arbeit wird auch von der experimentellen Anwendung der spiralbewehrten Kolonnen im sowjetischen Untergrundbahnbau berichtet.