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REINFORCED CONCRETE POST WITHOUT FORMWORK FOR POWER LINE POLES WITH A VOLTAGE OF 0.4 - 10 kV

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ABSTRACT

When using the technology of mold residues for the production of reinforced concrete structures, industrial construction can be carried out in accordance with the requirements of modern regulations. This allows projects to be developed individually, and production can be readjusted in a short time in accordance with emerging needs. In this regard, the possibility of using reinforced concrete racks produced by the technology of stand-off formwork for high-voltage lines is being considered. The goal is to develop a design of pre stressed stands for stand-off formwork on a standard basis of the product range for overhead line supports with a voltage of 0.4 ... 10 kV. This base consists of 16 brands of racks, 11 metal forms are used for their manufacture. The problem of establishing the minimum number (two) of cross-sections with different geometric dimensions for all brands of the offered racks has been solved, subject to the operational requirements and technological conditions of production. The proposed racks are reinforced only with high-strength wire reinforcement of the Br1400 class with a diameter of 5 mm (limitation of the technology of stand-off formwork molding), therefore, during their operation, the formation of cracks in the stretched zone is not provided. Qualitative features of racks for overhead transmission lines: low material consumption, versatility, manufacturability, innovation, which lies in the fact that their implementation is associated with the design, manufacture and testing of experimental products for use by specific consumers, i.e. commercialization.

KEYWORDS: ***post, form-less forming, cross-sectional configuration, tensile wire reinforcement, strength, fracture toughness.***

INTRODUCTION

When using modern technologies in the design and construction of a power transmission line, the costs of the construction and operation of such a line are reduced, the service life of building structures of the structure and their reliability are increased, the number of structure failures is reduced, leading to material losses from a decrease in the transit of electricity to consumers [1].

The technology of manufacturing reinforced concrete structures of stand-off formwork is progressive and is used in the construction industry in economically developed countries. When using this technology, industrial construction can be carried out in accordance with the requirements of modern regulatory documents, which allow projects to be developed individually, and the production of structures can be reoriented in a very short time in accordance with emerging needs. This means that different structural elements of buildings and structures can be produced on the same production line.

Features of non-form-forming structures are the absence of: transverse reinforcement, meshes, indirect reinforcement at the ends, reinforcement outlets, slinging loops, which is associated with the technology of manufacturing such structures. For example, for the manufacture of one linear meter of hollow-core floor slabs of stand-off formwork, 2.5 less metal is required in comparison with the manufacture according to the traditional scheme of aggregate-flow technology [2].

In Uzbekistan, the production of pre stressed hollow-core slabs of coverings, manufactured on the lines of stand-off formwork, has been established,

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thus, it becomes possible to expand the range of products produced on such lines.

It is most expedient to produce reinforced concrete structures at the stands without formwork that meet the following requirements:

- The product must be long, such as beams, floor slabs, piles, etc.;
- The dimensions of the cross-section of the product, based on the manufacturing technology, must be the same along the entire length, since the forming machine moves progressively along the stand.

Taking into account the requirements of the technology of forming reinforced concrete structures, it is of interest to produce racks for overhead power transmission line supports at stands without formwork.

The disadvantages of the well-known typical reinforced concrete vibrated racks (VR) for overhead lines (OL) [3, 4] are the complexity of manufacturing, caused by the fact that for each rack, reinforcement products (spirals, clamps, welded meshes) are made, arranged in the form, then there is a stage concreting, that is, each rack is formed in a separate form and the technological process of its manufacture is carried out for each rack separately. In addition, the process of pre stressing the working longitudinal reinforcement is not taken into account here, since such a process is also present in the manufacture of supports using the technology of stand-off formwork molding.

The building codes and regulations [5, 6] and the methodological manual [7] on the design of reinforced concrete structures do not regulate the design of structures (including racks for overhead line supports) produced using the technology of stand-off formwork molding, and which are reinforced only with pre stressed wire or rope fittings (without the use of tension-free fittings).

The management of the VR “GEO-BETON TRUST” invited the specialists of the Department of Building Structures of the Tashkent Architectural and Construction Institute to develop an innovative project “Development of the design of pre stressed poles for overhead lines 04 ... 10 kV with the possibility of their production by stand-off formwork”.

When developing the aforementioned racks, the bases of the product nomenclature given in the regulatory documents [3, 4] should be taken into account. These documents apply to standard racks for overhead line supports with a length of 8.5 to 16.4 m, reinforced with pre stressing bar reinforcement, concrete class B25 and B30. These posts have a trapezoidal cross-section (variable in length), in which the upper base is larger than the lower base (convenience in stripping finished products). The dimensions of the cross-sections of typical struts are taken depending on the corresponding values of the design bending moments taken by the struts from the action of operational loads, taking into account the limiting values of the width of the opening of cracks and deflections, and vary within the following limits (mm): b=165-390, $b_1 = 150 - 370$; $b_2 = 150 - 190$; $h_1 = 230 - 380$; $h_2 = 165 - 200$ (see fig.1).

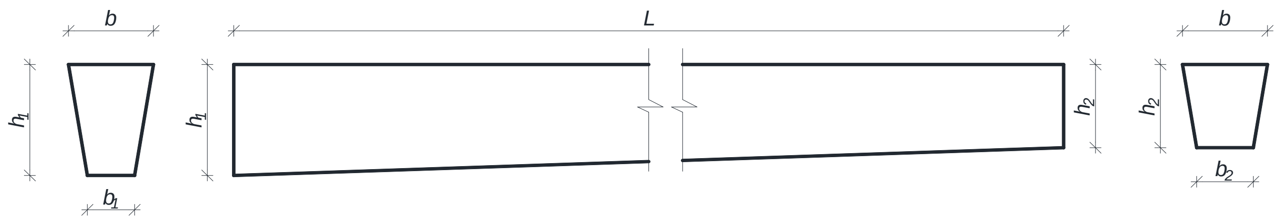

Fig.1. Geometry of typical racks [2, 6]

Thus, the nomenclature of products according to standard VR vertical racks consists of 16 grades, 11 metal molds are used for their manufacture.

In the terms of reference for the implementation of the above-mentioned project, the “Customer” established the following requirements.

1. Establish a unified geometry of the cross-section of the racks for the entire range of products under consideration, taking into account the technological limitations of forming machines while simultaneously meeting the requirements for strength, crack resistance, and stiffness for pre stressed reinforced concrete structures. At the same time, taking into account technological limitations, the height of the section of the product should be no more than 300 mm.

2. The developed racks for power transmission line supports must be reinforced with pre stressing wire reinforcement of class $\emptyset 5\ Vr1400$ and have concrete strength no higher than class B30, at which it would be possible to exclude the use of transverse reinforcement in the uprights (structures produced by the formless molding method are reinforced only with longitudinal pre stressed reinforcement and not allow you to install assembly - slinging loops (technological limitations of formwork-free molding).

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3. Propose schemes for reinforcement of racks for the entire range of products under consideration (layout of rods along the cross-section of racks).

4. To take part in the management and organization of the production of pilot batches of racks according to the developed technical regulations and the proposed project documentation.

5. Conduct a set of tests of racks from pilot batches for strength, crack resistance and stiffness in the factory.

Typical pre stressed supports of 04 ... 10 kV overhead lines [3, 4] are designed for operational and emergency loads, taking into account the assumption of cracks in concrete from 0.1 to 0.25 mm, depending on the type and classes of applied pre stressing reinforcement, as well as with taking into account meeting the regulatory requirements for rigidity.

It is known that a long service life of building structures, with the simultaneous action of force and environmental influences, leads to the appearance and development of damage, the main of which is corrosion damage. When assessing the structural safety of reinforced concrete structures, it is necessary to take into account corrosion damage in the stress-strain state of these structures. Due to corrosion, the strength and deformation parameters of concrete in the compressed zone and tensile reinforcement change with disruption of the adhesion of the rods to concrete, leading to a violation of the normative condition for limiting the height of the compressed zone, which can lead to brittle fracture of reinforced concrete structures during bending [8, 9, 11]. Corrosion damage leads to the formation and development of cracks, the rigidity of structures decreases, which contributes to the development of significant deformations.

In typical supports with pre stressing bar reinforcement with a diameter of 12-14 mm, when used in non-aggressive environments, cracks opening up to 0.5 mm will not lead to emergency situations. A decrease in the cross-sectional area of such reinforcement against corrosion over 40 ... 50 years of operation, with a high degree of probability, cannot occur by more than 10 - 15% of the initial cross-sectional area [11, 13]. 25 years of experience in the operation of overhead line supports with opening cracks of up to 0.5 mm shows that the reduction in the section from corrosion of steel rod reinforcement was no more than 5 - 7%.

With the same depth of corrosion of high-strength wire reinforcement with a diameter of 5 mm, the degree of corrosive wear turns out to be incomparably greater than that of bar reinforcement, and the risk of consequences is higher. Therefore, the operation of supports for supports reinforced with high-strength wire reinforcement with a diameter of 5 mm and below, with transverse cracks opening even 0.1 mm, is risky, especially when operating such supports in aggressive environments [11, 12, 13]. The danger of local corrosion damage to high-strength wire reinforcement in the area of transverse cracks is that it can lead, as noted above, to brittle destruction of the struts. Reducing the cross-section of the rods of high-strength wire reinforcement of the uprights by 60% leads to their rupture without necking[11].

Thus, the calculation of racks manufactured using the technology of stand-off formwork and reinforced with high-strength wire reinforcement Ø5 Vr1400 should be carried out without cracking in the concrete body from the action of possible operational loads [6, 14]. Compliance with the requirements for crack resistance and the thickness of the protective concrete stand, the use of high-strength concrete protects the pre stressed wire reinforcement of such stands for overhead line supports from corrosion and increases their durability [11, 12, 13, 15]. In addition, taking into account the peculiarities of the operation of racks for overhead lines and the likelihood of their operation in unfavorable conditions, the risks of cracking are reduced due to a higher level of pre-compression of the concrete of the rack with high-strength wire reinforcement, which makes it possible to preserve such reinforcement from corrosion for a long time.

To achieve the goal of development, expressed in the name of the above-mentioned project, the initial task was formulated - to determine the parameters and configuration of the cross-sections of the struts for the supports manufactured by stand-off formwork and taking into account the conditions of the manufacturing technology and the customer's requirements.

II. METHODOLOGY

It is known that one of the most significant issues in the development of the theory of reinforced concrete resistance is an increase in the span of a structure while minimizing the size of its cross section. In connection with this issue and others, the following is stated [17]: "Creation of new and development of existing methods for calculating concrete and reinforced concrete structures, providing the necessary reliability and durability, is the basis for the development of modern design solutions for buildings and structures that reduce the labor intensity of construction and allow you to get the maximum savings in materials." Thus, designers who want to implement an individual project cannot be satisfied with the existing approaches to the calculation of reinforced concrete structures based on a variety of design solutions that differ from the standard ones, for example, in the configuration of the cross-section of the structure. In this regard, the parameters of the cross-sections of the racks for the overhead line supports were assigned based on the following basic requirements:

- Ensuring the required strength, crack resistance and stiffness of the rack;

- The manufacture of a product (rack) must be versatile and technologically advanced.

The factor of versatility of racks for supports of overhead lines without formwork is the ability to produce products (racks) of any length and operational loads required for the consumer. From the standpoint of the innovative implementation of overhead line supports, manufacturability is the ability to produce products (stands) on an industrial scale with modern equipment (stand-off mold lines) with transformed geometric parameters of standard racks that do not worsen their strength and stiffness parameters [16].

Under operational loads, alternating forces (bending moments) appear in the section of the struts for the overhead line supports, therefore, the reinforcement scheme of its section is assumed to be symmetric. In this case, the rods of the pre stressed wire reinforcement are located on all corner sections of the rack section in groups with the same number of rods in each group (by analogy with the location of the pre stressed rod reinforcement at the cross-section corners of typical vibrated racks VR.

Thus, the shape and dimensions of the cross-section of the racks depend on:

- the area of the corner sections of the section with the largest number of rods in the “group”, taking into account the fact that the transfer strength of concrete R_{bp} (concrete strength at the moment of its compression) should be called at least 15 MPa and at least 50% of the accepted class of concrete in terms of compressive strength [7];
- the thickness of the concrete protective layer, which protects the stress-strain wire reinforcement of the rack from corrosion;
- strength and crack resistance of the rack section;
- Limitation of the technology of manufacturing structures by stand-off formwork molding along the height of the product.

The action of operational loads on the rack causes bending and, to a lesser extent, torques in it (the value of the ratio of torque to bending is in the range of 0.1 ... 0.4) [17]. Considering this specificity of the work of reinforced concrete racks for overhead line supports, the cross section of the proposed racks is left in the form of a trapezoid (quadrangle). The difference in comparison with the cross-sectional shape of a typical VR post is as follows: a larger size of the lower base of the trapezoidal cross-sectional shape is adopted as compared to the upper one. This cross-sectional shape was adopted with the need to establish the invariability of the shape of the freshly formed concrete body of the rack, manufactured using stand-off formwork technology.

The calculation of the supports of overhead lines, manufactured using the technology of stand-off formwork molding, and reinforced with wire reinforcement of the class $\emptyset 5\,Vr1400$, was carried out without the formation of cracks in the concrete body from the action of possible operational loads according to [6, 15]. In this case, the deflections of the racks when checking the calculated control load in terms of rigidity are less than the values of the control deflections of typical racks [3] from 4.5 to 7.6 times (depending on the brands of racks under consideration).

For racks up to 11.0 m long, a solid trapezoidal section is proposed (h = 245 mm, b = 150 mm - upper base; b_1 = 180 mm - lower base).

For racks with a length of 11.0 to 16.4 m, a trapezoidal section is also proposed (h = 300 mm, b = 205 mm; b_1 = 235 mm), but a cavity is provided along the entire length of the racks in the middle of the cross section of these racks.

It is known that concrete in the middle part with respect to the cross-section of reinforced concrete bending elements remains underutilized. Therefore, the design principle of floor slabs with different cross-sectional shapes is to exclude the maximum volume of concrete from the stretched section zone, leaving vertical ribs to ensure the strength of the slab along inclined sections [18]. The same factor is probably manifested in the reinforced concrete pillar of the overhead line support, if a cavity is placed along the entire length of the pillar in the middle part relative to its cross section. This cavity (void) does not impair the strength and stiffness characteristics of the proposed racks for the entire range of products under consideration. Thus, reducing the material consumption of the rack without reducing its strength ensures the economic efficiency of the structure.

It is known from the experience of designing hollow-core floor slabs that with an increase in the degree of hollowness of the slabs in excess of the “criterial value”, the bearing capacity of the slabs along normal sections is significantly reduced, due to the transition of the neutral line into the inter-cavity partitions (ribs) of the slab, as well as the strength along the inclined sections on the supporting sections of the slabs, in addition, the deformability of the slabs increases, i.e., its rigidity decreases. The same phenomenon appears in the hollow strut. Based on this reasoning, the solution of the problem under consideration is concretized. In addition, there is no need to find the optimal combination of the height and configuration parameters of the cross-section of the rack, since the criterion for the height of the cross-section is given.

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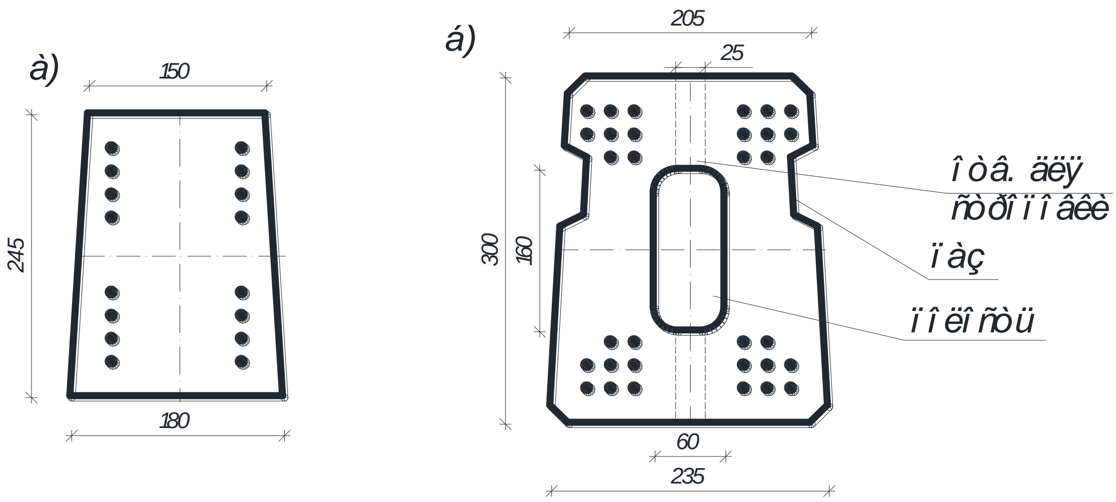

Fig. 2. Proposed cross-sections of stands of stand-off formwork for overhead lines with a voltage of 0.4 ... 10 kV and length: a) from 8.5 to 11.0 m; b) from 11 to 16.4 m.

III. CONCLUSIONS

1. For the reinforcement of the proposed racks across the entire range of products of stand-off formwork molding, 2.3 times less reinforcing steel is consumed than for typical vibrated racks throughout the range of products given in [3, 4].

2. The production of racks using the technology of stand-off formwork for overhead transmission lines is characterized by the following advantages over the production of vibrated racks (VR) according to the standard base of the nomenclature of products [3, 4].

- cheaper product cost;
- versatility and manufacturability;
- Guaranteed quality of products.

3. The proposed cross-section of hollow racks produced by stand-off formwork for overhead lines with a voltage of 0.4 ... 10 kV is declared in the Intellectual Property Agency of the Republic of Uzbekistan as a utility model with a priority date of 01.21.2020 (FAP 2020 0007).

4. Design documentation has been prepared and a draft technical specification has been developed for the production of stand-off formwork stands according to the proposed product range.

5. Work is underway to solve the following tasks on the problem under consideration:

- assessment of fracture toughness and strength by control tests of racks from pilot production batches for the possibility of producing racks of stand-off formwork for overhead transmission lines in an industrial scale;
- Optimization of the consumption of high-strength wire reinforcement for racks of different lengths at different values of operational loads outside the standard base of the product range [3].

Based on the results of these works, an article will be prepared for publication.

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