UDC 681.326

PRECONDITIONS OF CALCULATION SUPPORT ZONE OF PRESTRESSED CONCRETE BEAM WITH FLAT BENT-UP LONGITUDINAL COMPOSITE REINFORCEMENT UNDER THE EFFECT OF BENDS WITH TRANSVERS FORCE

ARTHUR HIL, YAHOR LAZOUSKI
Polotsk State University, Belarus

The article describes the preconditions for calculating the strength of the inclined sections of pre-stressed beams with a gentle contour reinforcement in the bending operation with a transverse force. Are presented assumptions and features of calculation of concrete structures with composite reinforcement. It noted the specificity of pre-stressing of curved composite rods.

In construction practice special place is occupied beamed reinforced concrete elements with a contour of the work of the longitudinal reinforcement from the lower zone to the upper zone of the supports. The introduction of such structures with metal pre-stressing reinforcement is appropriate and justified, that is caused by economic and operational efficiency. However, it should be noted that there are certain obstacles to the widespread use of these structures, namely the insufficient knowledge about of resistance such elements bending with transverse force. Should also pay attention to the fact that existing methods of calculation require clarification [1]. Even less studied is the question, and the ability to use as a bent reinforcement composite, namely, fiberglass and basalt, which is a promising direction [2]. No studies on the cross-sectional area at the cut bent elements flat bent-up fiberglass reinforcement. Today, these types of reinforcement are the most widespread in the construction of composite materials, as well as some of the most advanced materials, thanks to their advantages over steel reinforcement [3].

To develop the methodology for calculating the strength of the support areas of concrete elements with flat bent-up composite reinforcement consider the existing methods for calculating the strength of such sections with pre-stressed steel reinforcement. The basis for calculating resistance sloping sections of concrete elements with a flat bent-up of the longitudinal reinforcement is more rational to use a modified compression field theory (MCFT) [4], based on models of varying the angle, and the general deformation method [5]. The advantages of these methods first and foremost due to the fact that the method of calculation of these models more fully take into account the stress strain state in a diagonal crack, and is the final step in calculating the strength of sections under the joint action of all internal and external forces. [6] In general, the resistance of the sloping sections of pre-stressed bending element can be written as

$$V_{Rd} = V_{cd} + V_{sw} + V_p = \sigma_1 \cdot b_w \cdot z \cdot \cot\theta + \frac{A_{sw} \cdot f_{ywd} \cdot z}{s} + V_p \geq V_{sd}, \tag{1}$$

where σ_1 – average value of the major tensile stresses in the concrete, defined by the transformed strain diagram as a function of the relative principal tensile strain;

z – a pair of shoulder internal forces, defined as the distance between the resultant force in the compressed concrete zone and stretched straight longitudinal reinforcement;

θ – the angle of diagonal stripes in a predetermined section;

V_{sd} – transverse force caused by an external load;

V_p – the vertical component of the lateral force perceived bent at an angle α to the estimated reinforcement sections within the anchoring zone length is determined by the following equation:

$$V_p = \sigma_{pd,inc} \cdot A_{p,inc} \cdot \sin\alpha = \frac{l_x}{l_{bpd}} \cdot f_{pd,inc} \cdot A_{p,inc} \cdot \sin\alpha, \tag{2}$$

where l_x – the distance from the support to the section under consideration;

l_{bpd} – the length of the anchoring zone.

For cross sections outside the anchoring zone $\sigma_{pd,inc} = f_{pd,inc}$.

Application of this technique to calculate the strength support zones bent elements with composite reinforcement requires consideration of the characteristics and assumptions in the design of such elements. Calculation of the elements should be performed for a simple flat sections based on strain compatibility equations. It is worth noting some of the basic assumptions for bent elements with composite reinforcement:

– hypothesis of plane sections;

– after the formation of cracks in the concrete inclined section extended area is not included in the resistance of the section;

– shear deformations can be ignored due to the small bending deformations;

– are used in the calculation of diagrams describing the relationship of stress and strain of concrete and reinforcement.

Also worth noting is the input of the concept of nominal state balanced deformations in sections of concrete elements reinforced composite rods. This condition is deemed to have occurred when a section of concrete reinforcement element relative deformation of stretching a polymer composite reaches its limiting value (ε_{frpu}) and simultaneously compression deformation relative most compressed faces concrete section reaches its limiting value ($\varepsilon_{cu} = 0.0035$). Upon the occurrence of such a state of the concrete element, reinforced composite reinforcement, insert decreases suddenly, without any visible strain, as this type of reinforcement is a brittle material and has no flow properties (absolutely linearly deformable material). Thus, the plastic and deformation properties in pre-stressed concrete elements with steel and composite reinforcement differ from each other. Under the influence of the load pre-stressed concrete beams with steel reinforcement are deformed elastically until the beginning of the destruction, and the time of occurrence of fracture strain begin to grow indefinitely because of the strength of steel. However, due to the linear deformability of the composite rods pre-stressed concrete elements well before the destruction of the deformed elastically, but with an increase in load current, such elements continue to deform elastically until failure occurring as a result of the exhaustion of its load-bearing capacity or stretched composite reinforcement or compressed concrete zone or at the same time as the tension reinforcement and concrete compressed zone.

It is also necessary to take into account the specifics of the pre-stressing of curved composite rods. Due to the fact that the composite rods are elastically deformable, when a decrease in their bending tensile strength. Thus, the voltage generated at the tension stage reinforcement in the composite rod with a flat bent-up (having a curvilinear outline in the longitudinal direction of the concrete element) must be reduced because it is necessary to consider the appearance of additional stresses in the curved portion of the rod. The level of stress achieved at a bend of the composite rod will depend on the radius of curvature at the inflection point of the rod, the elastic modulus and the cross section of the rod characteristics. Stress may be determined by the following equation [7]:

$$R_n = \frac{r^2}{2} \cdot \sqrt{\frac{E_{frp} \cdot \pi}{P \cdot (1 - \cos\theta)}}\,, \tag{4}$$

where E_{frp} – modulus of elasticity of the composite rod;

y – the distance from the center of gravity to the verge of a stretched composite curved rod (the distance equal to the radius rod);

R_{ch} – radius of curvature rod at the point of inflection.

It should also pay attention to the fact that the effectiveness of pre-stressing rods produced from a polymer composite is significantly reduced when the stresses in the composite rod as a result of bending, are deducted from the value of allowable stress generated in the composite reinforcement at the stage of its tension. The resulting tension in the web of a polymeric composite A_{frp} area with a force of its tension P_j is given by:

$$\sigma_h = \frac{P_j}{A_{frp}} + \frac{E_{frp} \cdot y}{R_{ch}}\,. \tag{5}$$

It is worth paying attention to the fact that the value of the permissible voltage level rods of polymer composite reinforcement tension stage and transfer stage effort compression on concrete for concrete beams are limited to values much lower than with short-term tensile strength rods from polymer composite [8, 9]. For example, for polymer composites reinforced with glass fiber, the voltage on the reinforcement tension stage by pulling on the supports is 30% of the ultimate strength.

Thus, the use of methods of calculating strength support zones of pre-stressed concrete beams with a flat bent-up of the longitudinal reinforcement in composite action with the bending of the transverse force requires substantial consideration of all the characteristics and properties of composite reinforcement, as well as its work in the concrete.

REFERENCES

1. Кривицкий, П.В. Влияние основных факторов на сопротивление преднапряженных железобетонных балок с канатной отогнутой арматурой изгибу с поперечной силой / П.В. Кривицкий, В.Н. Малиновский // Вестник БрГТУ. – 2016. – № 1 (97) : Строительство и архитектура. – С. 93–97.
2. Гиль, А.И. Перспективы применения пологоотогнутой стеклопластиковой арматуры в зоне среза изгибаемых армобетонных элементов / А.И. Гиль, Е.Д. Лазовский // Вестник Полоцкого государственного университета. Серия F, Строительство. Прикладные науки. – 2016. – № 8. – С. 61–65.
3. Гиль, А.И. Стеклопластиковая и углепластиковая арматура в строительстве: преимущества, недостатки, перспективы применения / А.И. Гиль, Е.Н. Бадалова, Е.Д. Лазовский // Вестник Полоцкого государственного университета. Серия F. Строительство. Прикладные науки. – 2015. – № 16. – С. 48–53.
4. Vecchio, F.J. The Modified Compression Field Theory for Reinforced Concrete Elements Subjected to Shear / F.J. Veccio, M.P. Collins // ACI JOURNAL, Proceedings. – 1986. – V. 83, No. 2. – P. 219–231.
5. Бетонные и железобетонные конструкции : СНБ 5.03.01-02. – Введ. 20.06.2002. – Минск : М-во архитектуры и стр-ва Респ. Беларусь, 2003. – 143 с.
6. Малиновский, В.Н. Особенности расчета и конструирования приопорных зон преднапряженных железобетонных балок с пологим отгибом продольной стальной арматуры / В.Н. Малиновский, П.В. Кривицкий // Проблемы современного бетона и железобетона : сб. науч. тр. – 2015. – № 7. – С. 78–89.
7. Design Recommendations for Concrete Structures Prestressed with FRP Tendons : Final Report / University of Wyoming, Pennsylvania State University, University of Missouri-Rolla ; ed.: Dolan C.W. [et al.] – 2001. – FHWA – DTFH61-96-C-00019.
8. The Canadian Highway Bridge Design Code : CAN/CSA-S06-06. – Introduced November, 2006 – Ottawa, Ontario : Canadian Standards Association, 2006.
9. Design and Construction of Building components with Fibre Reinforced Polymers : CAN/CSA-S806-02. – Introduced May, 2004 – Ottawa, Ontario : Canadian Standards Association, 2004.