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ANALYSIS OF EXISTING METHODS FOR DETERMINING LENGTH FIBERGLASS ANCHORAGE REINFORCEMENT IN CONCRETE

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Considered and analyzed existing methods used for calculating the anchorage length of reinforcement in concrete. Determined by the use of techniques for fiberglass reinforcement.

Polymer materials and polymer composites have gained an important place in modern technology. Reinforced polymer composite materials (PCM) with unidirectional fiber orientation substantially exceed all modern metal construction materials. These advantages are even more significant if we take into account the low density of PCM (1300-2000 kg / m^3).

For the moment the most common in the construction of composite material is fiberglass reinforcement. Fiberglass reinforcement is characterized by a heterogeneous system consisting of oriented glass fibers and a polymer binder. Fiberglass reinforcement properties depend on the properties and characteristics of the glass fibers and the polymer matrix structure, and physic-chemical interactions of these components, they work together in the perception of external loads, corrosive reagents and other factors. Knowledge of the properties of the raw materials allows you to control the properties of fiberglass reinforcement. High-strength glass fiber almost entirely perceived influence of tensile forces, determines the deformation properties of reinforcement, explains the change in strength characteristics under the influence of external factors. For all types of fiberglass reinforcement elongation is directly proportional to tensile loading up to failure. This is the cause of brittle failure of reinforced concrete structures reinforced with fiberglass reinforcement only. In [7], confirmed that the strength and the tensile modulus substantially depend on the diameter of the bar: the smaller the diameter of the armature, the higher its strength and modulus.

Properties that do not allow to perform a complete replacement of the metal reinforcement in the composite:

- Low modulus of elasticity;
- Low strength transverse loads;
- Lower fire products, reinforced composite reinforcement;
- Difficulties in the manufacture of prestressed structures;
- Knowledge gap on the bond strength of composite reinforcement with concrete.

Adhesion to concrete reinforcement is a key factor in ensuring their co-operation in reinforced concrete structures. Investigation of the influence of the diameter and length of bars embedment strength and deformability of adhesion to concrete composite reinforcement in flexural elements received considerable attention.

Made in Belarus and imported to the republic composite bars is wide variation in the physical and mechanical characteristics, geometrical parameters and raw materials. The lack of regulations standards the requirements for composite reinforcement, leading to differences in manufacturing technology and the geometric dimensions of periodic profile. Fittings from different manufacturers will have excellent adhesion characteristics with concrete.

The length of the anchoring fiberglass reinforcement in concrete may be determined according to the guidelines SNB 5.03.01-02, SNIP 2.03.01-84 * TAP EN 1992-1-1-2009, CAN / CSA-S6-00, CAN / CSA-S6-02, JSCE.

Methods for calculating the SNB 5.03.01-02 is based on tests with a favorable combination of structural factors (large concrete cover, concrete subjected to compression).

Calculation of anchoring tensile reinforcement is made using the parameter – the basic (nominal) length of anchoring (*lb*). This value is determined by the conditions under which the force in the longitudinal reinforcement is perceived resistance of concrete adhesion to the reinforcement (f_{bd}) on the perimeter of the bar (U_s) over the length of the anchorage.

Adhesion resistance determined depending on the tensile strength of concrete (f_{ctd}).

$$f_{bd} = \eta_1 \cdot \eta_2 \cdot \eta_3 \cdot f_{ctd}.$$

Basic anchorage length is determined by the conditions under which the clutch stress contact concrete and reinforcement do not reach the limit values to achieve in the armature stress corresponding to the Settlement armature resistance (f_{yd}).

$$l_b = \left(\frac{\varnothing}{4}\right) \cdot \left(\frac{f_{yd}}{f_{bd}}\right).$$

Hence, the base anchoring length, according to the calculated dependence, does not guarantee the reliability of the anchorage at stresses in the armature corresponding to the physical limit yield.

On the basis of the basic anchorage length is determined by the calculated anchoring length, taking into account the additional factors: the thickness of the concrete cover, transverse compression within the length of anchoring, the ratio between the actual and the desired area of the valve on the calculation, etc.

$$l_{bd} = a_1 \cdot a_2 \cdot a_3 \cdot a_4 \cdot l_b \cdot \frac{A_{s,req}}{A_{s,prov}} \geq l_{b,\min} .$$

The minimum length of anchoring $l_{b,\min}$ must not be less than a multiple of l_b (Tab. 1).

Table 1. – The minimum length of anchoring $l_{b,\min}$

Normative document	For the tensilebar is equal to the greater of the following values:	For compressed bar equal to the greater of the following values:
SNB 5.03.01-02	{0,6 l_b; 15∅; 100 mm}	{0,3 l_b; 15∅; 100 mm}

It can be concluded that the SNB 5.03.01-02 guidelines allows large stocks when determining the length of the anchoring base and minimum values of the tensile length of the anchoring rods;limits the minimum length of the anchoring bars is cut off in span and for intravascular inner face of the support.

When using this method for fiberglass reinforcement, you must first calculate the required value of the coefficient η_3.

$$\eta_3 = \frac{\sigma_{s,\max} d}{4\eta_1 \cdot \eta_2 \cdot f_{ctd} \cdot l_{задан}} .$$

Calculation of anchoring tensile reinforcement according to EN 1992-1-1 TAP guidelines is also performed using the parameter – the basic (nominal) length of anchoring ($l_{b,rqd}$),which is determined by the worst combination of structural factors (minimally acceptable standards of concrete cover, the distance between the bars, etc.), which can be reduced under favorable conditions.

The formula for determining the basic anchorage length does not depend on the calculated armature resistance, and depends on the operating stress in the bar (σ_{sd}) in place, which is measured with the anchoring must be taken into account the form of reinforcing steel and adhesion properties to the bars.

$$l_{b,rqd} = \left(\frac{\varnothing}{4}\right) \cdot \left(\frac{\sigma_{sd}}{f_{bd}}\right).$$

Ultimate bond stress (f_{bd}) should be sufficient to avoid the failure of the debonding.

The estimated length of the anchoring l_{bd} determined based on the length of the anchoring base, taking into account the effect of the bar at a sufficient protective layer; the minimum thickness of the protective layer of concrete, etc.:

$$l_{bd} = a_1 \cdot a_2 \cdot a_3 \cdot a_4 \cdot a_5 \cdot l_{b,rqd} \geq l_{b,\min} .$$

The minimum length of anchoring $l_{b,\min}$ must not be less than a multiple of l_b (Tab. 2).

Table 2. – The minimum length of anchoring $l_{b,\min}$

Normative document	For the tensilebar is equal to the greater of the following values:	For compressed bar equal to the greater of the following values:
TAP EN 1992-1-1-2009	{0,3 l_b; 10∅; 100 mm}	{0,6 l_b; 10∅; 100 mm}

When calculating the length of the anchoring SNIP 2.03.01-84 longitudinal rods are tensile and compressed reinforcement should be instituted for the normal to the longitudinal axis of the cross section for the length of not less than l_{an}, defined by the formula:

$$l_{am} = \left(w_{am} \frac{R_s}{R_b} + \Delta\lambda_{am} \right) d .$$

But at least $l_{an} = \lambda_{an} d$.
Values w_{an}, $\Delta\lambda_{an}$, λ_{an} defined in Table 3.

Table 3. The coefficients for determining the anchoring Free of tension reinforcement

Operating conditions Free of tension reinforcement	The coefficients for determining the anchoring Free of tension reinforcement							
	Periodic Profile				Smooth			
	w_{an}	$\Delta\lambda_{an}$	λ_{an}	l_{an}, mm	w_{an}	$\Delta\lambda_{an}$	λ_{an}	l_{an}, mm
			No less				No less	
1. Closing the valve:								
• Tensile in cracked concrete	0,7	11	20	250	1,20	11	20	250
• Compressed or tensile in the compressed concrete	0,5	8	12	200	0,80	8	15	200
2. Overlap joints reinforcement								
• In tensile concrete	0,9	11	20	250	1,55	11	20	250
• The compressed concrete	0,65	8	15	200	1,00	8	15	200

For the elements of fine concrete values are increased by l_{an} $10d$ for concrete in tension and $5d$ – compressed. If rods anchorage bars are delivered with a margin on the cross-sectional area compared to the required calculation, the anchorage length may be reduced, by multiplying by the ratio required for the calculation and the actual area of the valve section.

The Canadian Standards [13] and [12] proposed formula to calculate the required length of anchoring NCA. In the recommendations [13] provides for the estimated demand for carbon fiber and organic-fitting. Fiberglass reinforcement only considered as constructive. Standards [12] provide for the use of glass-fiber reinforcement, but only as a tendon whenever possible to ensure its longevity.

The formula determining the necessary anchorage length of the zone is based on a similar formula for the steel reinforcement of the Canadian regulations and has empirically established coefficients, specifying actual work for steel reinforcement:

$$l_d = 0.45 \frac{k_1 k_4}{d_{cs} + K_{tr} \dfrac{E_f}{E_s}} \cdot \frac{f_{yd}}{f_{bd}} A,$$

where l_d – anchoring zone length;

k_1 – the coefficient corresponding to the position of reinforcement;

d_{cs} – the shortest distance from the core center to the edge of concrete or step bars, mm;

K_{tr} – index of transverse reinforcement;

k_4 – additional indicator clutch NCA, equal to the ratio of strength NCA adhesion to strength clutch steel bars, but not more than 1.

In accordance with Japanese standards JSCE [11] the length of the anchoring base is determined by the formula:

$$l_d = \alpha_1 \left| \frac{f_{fd}}{4 f_{bod}} \right| d > 20d\ ,$$

where

- α_1 accepted:
  - 1,0 for $k_c \leq 1.0$;
  - 0.9 for $1.0 < k_c \leq 1.5$;
  - 0.8 for $1.5 < k_c \leq 2.0$;
  - 0.7 for $2.0 < k_c \leq 2.5$;
  - 0.6 for $2.5 < k_c$;
- calculated strength f_{bod} clutch is determined by the formula

$$f_{bod} = \alpha_2 \left(\frac{0.28 f_{ck}^{\frac{2}{3}}}{\gamma_c} \right) < 3.2 \text{ MPa},$$

γ_s = 1.3 at f_{ck} < 50 MPa and 1.5 for $f_{ck} \geq$ 50 MPa;

α_2 – ratio, which expresses the ratio of the strength of adhesion to the NCA corrugated steel reinforcement bond strength, but not more than 1.0.

A total of, the following conclusions.

Standards of various countries provided many techniques to determine the length of anchorage reinforcement in the concrete, but not all of them adapted to the fiberglass reinforcement.To determine the applicability of each of the methods for calculating the additional investigations necessary.

REFERENCESE

1. Холмянский, М.М. Контакт арматуры с бетоном / М.М. Холмянский. – М. : Стройиздат, 1981. – 184 с.
2. Фролов, Н.П. Стеклопластиковая арматура и стеклопластбетонные конструкции. – М. : Стройиздат, 1980. – 104 с.
3. Коррозия бетона и железобетона, методы их защиты / В.М. Москвин [и др.]. – М. : Стройиздат, 1980. – 536 с.
4. Астрова, Т.И. Анкеровка стержней арматуры периодического профиля в обычном и предварительнонапряжённом железобетоне / Т.И. Астрова // Расчет железобетонных конструкций : сб. тр. – М. : НИИЖБ, 1961. – С. 74–126.
5. Бетонные и железобетонные конструкции : СНБ 5.03.01-02.
6. Проектирование железобетонных конструкций : ТКП EN 1992-1-1-2009. Еврокод 2.
7. Особенности сцепления с бетоном стержневой арматуры различных профилей / А.С. Семченков [и др.] // Экспертиза. – 2008. – № 8. – С. 58–62.
8. Хотько, А.А. Расчетная оценка анкеровки в бетоне ненапрягаемой арматуры с различными видами периодического профиля / А.А. Хотько, Ю.В. Попков, А.В. Василевский // Перспективы развития новых технологий в строительстве и подготовке инженерных кадров Республики Беларусь : сб. науч. тр. – Могилев : Белорус.-Рос. ун-т, 2005. – С. 480–487.
9. Бабич, Є. М. Зчеплення арматури класу А500С з бетоном різноїміцності / Є.М. Бабич, О.С. Чапюк // Механіка і фізика руйнування будівельних матеріалів та конструкцій.
10. О нормировании анкеровки стержневой арматуры / И.Н. Тихонов [и др.] // Бетон и железобетон. — 2006. – №3. – С. 2–7.
11. JSCE, Recommendation for Design and Construction of Concrete Structures Using Continuous Fiber Reinforcing Materials, Tokyo,Japan: Japan Society of Civil Engineers, 1997.
12. CAN/CSA-S6-00, CanadianHighBridgeDesignCode, CanadianStandardsAssociation, 2000.
13. CAN/CSA-S6-02, Design and Construction of Building Components with Diber-Reinforced Polymers, Canadian Standards Association, 2002.