INTERSTATE COUNCIL FOR STANDARDIZATION, METROLOGY AND CERTIFICATION
(ISC)

INTERSTATE STANDARD **GOST 31938 - 2012**

FIBRE-REINFORCED POLYMER BAR FOR CONCRETE REINFORCEMENT

General technical specifications

(ISO 10406-1:2008, NEQ)

Official publication

/Seal: territorial subdivision of propagation of regulatory technical documentation and scientific and engineering information No 1. Moscow.* Copy is an official document* *Illegible*/

Moscow
Standartinform
2014

Introduction

Goals, main principles, and standard operating procedures of interstate standardization in construction are established by GOST 1.0—92 «State System for Standardization of Russion Federation. Basic principles» and GOST 1.2—2009 « Interstate system for standardization. Interstate standards, rules and recommendations on interstate standardization. Rules for development, taking over, application, renovation and cancellation»

Information on the standard

1 DEVELOPED BY RESEARCH INSTITUTE OF CONCRETE AND REINFORCED CONCRETE (NIIZHB) NAMED A.A. GVOZDEV and Reinforced Concrete "Concrete and Reinforced Concrete Research Institute of Moscow", "Research Centre of Construction" JSC, "Biysk factory of glass-fibre reinforced plastics" LLC with the participation of "TMB" LLC

2 INTEGRATED BY Interoperability Technical Committee TK 465 "Construction"

3 APPROVED BY Interstate Scientific and Technical Commission for Standardization, Technical rate setting and Compliance assessment in Construction (proceedings of 18 December, 2012 No. 41)

For acceptance voted:

Short name of country acc. to MK (ISO 3166) 004-97	Country code acc. to MK (ISO 3166) 004-97	Short name of State Administrative Body for Construction
Azerbaijan	AZ	State Committee for Construction
Armenia	AM	Ministry of Urban planning
Belarus	BY	Ministry of Architecture and Construction
Kirghizia	KG	State Committee for Construction
Moldova	MD	State Committee for Construction
Russia	RU	Ministry of Regional Development
Tajikistan	TJ	Construction and Architecture Agency and affiliated to the government
Uzbekistan	YZ	State Committee of Architecture and Construction

4 This standard is developed on the basic of the main statutory regulations ISO 10406-1:2009 Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 1: FRP bars and grids in terms of test methods.
Degree of conformity — inequivalent (NEQ)

5 By order of Federal Agency on Technical Regulating and Metrology dated 27 December, 2012 No. 2004-st interstate standard GOST 31938 -2012 has been put into effect as a national standard of the Russia Federation since 1 January, 2014.

6 PUT INTO EFFECT FOR THE FIRST TIME

Information on changes to this standard is published in annual reference index "National standards" (as of 1 January of the present year), and amendment text — in monthly reference index "National standards". In the case of oversight (replacement) or cancellation of this

standard, relevant notification will be published in monthly reference index "National standards". You can also find relevant information, notification and texts in information system of common use — at official website of Federal Agency on Technical Regulating and Metrology on the internet

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INTERSTATE STANDARD

FIBRE-REINFORCED POLYMER BAR FOR CONCRETE REINFORCEMENT

General specifications

Date of introduction —2014—01—01

1 Scope

This standard establishes General specifications and is applied to fibre-reinforced polymer ribbed bar (FRP bar) meant for reinforcement of conventional and restressed of building constructions and elements, used in mediums with different attack degrees, agreeable to the standards of fire resistance as per GOST Standard 30247 and fire safety as per GOST Standard 30403.

This standard is not applied to composite polymeric bars of smooth airfoil and composite polymeric flexible couplers.

2 Normative references

The following references to standards are used in this standard:

GOST 8.207—76 State system for ensuring the uniformity of measurements. Direct measurements with multiple observations. Methods of processing the results of observations. Basic principles

GOST 12.1.044—89 Fire and explosion hazard of substances and materials. Nomenclature of indices and methods of their determination

GOST 17.2.3.02—78 Regulations for establishing permissible emissions of noxious pollutants from industrial enterprises

GOST 166—89 (ISO 3599—76) Vernier callipers. Specifications

GOST 427—75 Measuring metal rules. Basic parameters and dimensions. Specifications

GOST 3560—73 Sealing tape

GOST 4651—82 Plastics. Compression test method

GOST 6507—90 Micrometers. Specifications

GOST 7502—98 Measuring metal tapes. Specifications

GOST 10884—94 Thermomechanically hardened steel bars for reinforced concrete constructions. Specifications

GOST 12004—81 Reinforcing-bar steel. Tensile test methods

GOST 12423—66 Plastics. Standard atmospheres for conditioning of test specimens (sample)

GOST 14192—96 Marking of cargoes

GOST 14359—69 Plastics. Testing method. General requirements of the methods of mechanical testing

GOST 15139—69 Plastics. Methods for the determination of density (volume mass)

GOST 15150—69 Machines, instruments and other industrial products. Modifications for different climatic regions. Categories, operating, storage and transportation conditions as to environment climatic aspects influence

GOST 16504—81 The state system of testing products. Product test and quality inspection. General terms and definitions

GOST 17308—88 Twine. Specifications

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GOST 28840—90 Machines for tension, compression and bending testing of materials. General technical requirements

GOST 30108—94 Building materials and elements. Determination of specific activity of natural radioactive nuclei

GOST 30247.0—94 Elements of building constructions. Fire resistance tests methods. General requirements

GOST 30403—96 Building structures. Fire hazard test methods

Note — When applying this standard you are advised to check if reference standards are in force in information system of common use — at official website of Federal Agency on Technical Regulating and Metrology on the internet or annual reference index "National standards", which is published as of 1 January of the present year, and releases of monthly reference index "National standards" for the present year. If reference standard is replaced (changed), when applying the standard you should follow replaced (changed) standard. If reference standard is cancelled without its replacement, provision where there is a reference to it, is applied without touching this reference.

3 Terms and definitions

Terms in this standard are applied per GOST Standard 10884 and GOST 12004, as well as the following terms with relevant definitions:

3.1 **composite**: Solid product comprised of two or more materials that are different from each other on form and/or phase state, and/or chemical composition, and/or properties fastened together, as a rule, with physical link and having interface between obligatory material (matrix) and their fillers, including reinforcing fillers.

Note — Matrix and composite filler form single structure and act jointly providing necessary properties of end item for its functional purpose in the best possible way.

3.2 **matrix of polymer composite**; matrix. A structure made of hardened thermosetting resin that provides wholeness of polymer composite, responsible for transmission and distribution of tensions in reinforcing filler, and defines heat stability, moisture resistance, fire resistance and chemical stability of polymer composite.

3.3 **thermosetting resin**: resin, which when hardening on exposure to temperatures and/or due to chemical reaction irreversibly converts to hard, infusible and insoluble material with three-dimensional grid-type structure.

Note — Thermosetting resins refer to unsaturated polyester, epoxy, vinylester, phenolic and other types of organic resins.

3.4 **filler of thermosetting resin**; filler; Material or product connected with thermosetting resin prior to hardening process to change or give required properties to resin and/or matrix, or reduce the value of end production.

3.5 **reinforcing agent**: Material or article connected with thermosetting resin prior to hardening process to improve physical and mechanical characteristics of polymer composite.

Notes

1 "Reinforcing agent" in this standard means reinforcing filler made of continuous fibre. This term is not a synonym to the term "filler".

2 Continuous reinforcing agents of glass fibre, basalt fibre, carbon and aramid fibre are used to produce FRP bars.

3.6 **fibre**: Flexible extensive, continuous and solid object of limited length with small cross dimensions in relation to length, being applied for production of fibrous materials meant for polymer composites reinforcement.

Notes

1 Cross dimensions refer to thickness or diameter of fibre.

2 Depending on manufacturing process, there are continuous or staple fibres.

3.7 **glass fibre**: Fibre for polymer composites reinforcement generated from melt of

inorganic glass.

3.8 **basalt fibre**: Fibre for polymer composites reinforcement generated from melt of basalt or gabbrodiabase.

3.9 **carbon fibre**: Fibre for polymer composites reinforcement generated by pyrolysis of precursors organic fibres, which contains not less than 90 % of carbon mass.

Notes

1 Precursors refer to, for example, polyacrylonitrile or hydrated cellulose fibres.

2 Depending on ultimate strength and modulus of elasticity, carbon fibres are divided into general-purpose, high-strength, intermediate modulus, high-modulus and ultrahigh modulus fibres.

3.10 **aramid fibre**: Fibre for polymer composites reinforcement generated from linear fibre-forming polyamides, where not less than 85 % of amido groups are directly connected with two aromatic rings.

3.11 **glass composite**: Polymer composite containing continuous reinforcing agent from glass fibre.

3.12 **basalt composite**: Polymer composite containing continuous reinforcing agent from basalt fibre.

3.13 **carbon composite**: Polymer composite containing continuous reinforcing agent from carbon fibre.

3.14 **aramid composite**: Polymer composite containing continuous reinforcing agent from aramid fibre.

3.15 **combined composite**: Glass composite or basalt composite, or carbon composite, or aramid composite, additionally filled with continuous reinforcing agent from other type or types of fibre.

3.16 **composite reinforcement of die-rolled section**; composite polymeric reinforcement; FRP bar; Power bar with equally spaced on a surface and at angle to its longitudinal axis anchoring layer made of thermosetting resin, continuous reinforcing agent and other fillers.

3.17 **outside diameter of composite polymeric reinforcement**; outside diameter; Diameter allowing to identify nominal diameter by direct measuring the tops of periodical lugs on power bar.

3.18 **nominal diameter of composite polymeric reinforcement**; nominal diameter: Diameter of equivoluminar round plain bar considering allowable variations indicated in reinforcement designation used in calculations of physical and mechanical characteristics and structural analyses.

3.19 **cross section nominal area of composite polymeric reinforcement**; cross section nominal area: Cross section area, which is equivalent to cross section area of round plain bar of the same nominal diameter

3.20 **ultimate strength of concrete bond**: Shear stresses at the boundary of concrete bond arising during pulling reinforcement out concrete at the moment that precedes bond boundary destruction.

3.21 **ultimate strength in cross section**: Shear stresses arising in reinforcement from its exposure to lateral shear.

3.22 **ultimate service temperature**: Temperature, by which in case of its exceeding, physical and mechanical reinforcement characteristics as a result of polymer composite matrix softening fall off.

3.23 **power bar**: Solid bearing bar of reinforcement defining stress-strain properties.

3.24 **anchoring layer**: Transverse projections generated from winding on power bar of continuous fibre layer designed for hardening of a bond between concrete and reinforcement.

3 25 **die-rolled section step**: Distance between centres of two consecutive transverse projections, changed in parallel to longitudinal axis of power bar.

4 Classification, basic parameters and dimensions

4 1 By type of continuous reinforcing agent FRP bars are divided in the following types:

ASK — glass composite;

ABK— basalt composite;

AUK— carbon composite:

AAK— aramid composite;

AKK— combined composite.

4.2 FRP bar is produced in nominal diameters listed in the table 1.

Table 1

Nominal diameter d/mm	4	6	8	10	12	14	16	18	20	22	25	28	32

Note – It is allowed to produce FRP bars with other nominal diameters subject to conformity with requirements of this standard.

4.3 Value of FRP bar outside diameter should not be less than value of diameter indicated on manufacturing documentation.

4.4 FRP bar may have different die-rolled section providing required bond strength with concrete, incl. after exposure to corrosive mediums.

4.5 Manufacturer's documents on specific produced by him types of FRP bars must state the following geometrical dimensions of geometrical dimension of die-rolled section with extreme deviations:

- nominal diameter;
- outside diameter;
- die-rolled section step;
- cross section nominal area.

4.6 FRP bars are produced in the form of bars with fixed length of 0.5 to 12.0 m with length step of 0.5 m, it is allowed to produce bars of greater length.

4.7 Extreme deviations in the length of measuring bars must comply with meaning listed in the table 2.

Table 2

Length of bars, m	Extreme deviations in the length, mm
Up to 6 incl.	+25
More than 6 » 12 »	+35
» 12	+50

4.8 FRP bar with nominal diameter of 4 to 8 mm may be supplied in hanks or drums.

4.9 Minimum diameter of a hank or a drum d6, mm, must provide FRP bar safety in all conditions of its transportation and storage before use, and it is calculated by formula

$$d_б \geq 2\, d\, \frac{E_f}{\sigma_в}, \quad (1)$$

where d— nominal diameter, mm;

σв — ultimate strength limit, MPa;

Ef— modulus of elongation MPa.

4.10 Symbol of FRP bar must include: symbol of product type in terms of reinforcement fibre as of 4.1, nominal diameter, amount of strength under tension, elongation modulus value under tension and designation of this standard.

Examples of symbol:

- reinforcement of glass composite, with diameter of 12 mm, amount of strength under tension 1000 MPa, modulus of elongation 50 HPa:

ASK-12-1000/50 — GOST 00000— 2012

- composite combined reinforcement containing at the same time continuous reinforcing

agents of glass fibre and basalt fibre (reinforcing filler of glass fibre is principal, of basalt fibre – additional), with diameter of 10 mm, amount of strength under tension 1300 MPa, modulus of elongation 90 HPa:

AKK(SB)-10-1300/90—GOST 00000-2012

5 Technical specifications

5.1 Main indicators and characteristics

5.1.1 FRP bar must be produced according to the production documentation approved in accordance with the established procedure, and meet the requirements of this standard.

5.1.2 FRP bar must be produced from thermosetting resin and contain obligatory continuous reinforcing filler in amount not less than 75 % by weight.

5.1.3 As for the physical and mechanical performance, FRP bar must comply with requirements listed in the table 3.

Table 3

Indicator name	Regulation
Ultimate strength limit qa, MPa, not less	As required in the table 4
Modulus of elongation Ef, HPa, not less	As required in the table 4
Ultimate compression strength qa, MPa, not less	As required in the table 4
Ultimate strength in cross section, MPa, not less	As required in the table 4
Ultimate strength of concrete bond, MPa, not less	12
Reduction of ultimate strength limit after its exposure to alkaline medium, %, not less	25
Ultimate strength of concrete bond after its exposure to alkaline medium, MPa, not less	10
Ultimate service temperature T, °C, not less	60

5.1.4 FRP bar stress-strain properties of different types must comply with requirements listed in the table 4.

Table 4

Item	ASK	ABK	AUK	AAK	AKK
Ultimate strength limit, MPa, not less	800	800	1400	1400	1000
Modulus of elongation EF, HPa, not less	50	50	130	70	100
Ultimate compression strength, MPa, not less	300	300	300	300	300
Ultimate strength in cross section, MPa, not less	150	150	350	190	190

5.1.5 Ultimate strength limit and modulus of elongation of FRP bar must be not less than the amount specified in manufacturer’s documents. If manufacturer’s documents contain higher amounts of strength and modulus of elasticity, you should follow the requirements of manufacturing documentation.

5.1.6 Climatic modification of FRP bar — UHL 2 (moderately-cold climate) as per GOST Standard 15150.

5.2 Appearance standards

5.2.1 Identification characteristics of FRP bar describing trademark, geometric metrics and parameters of die-rolled section must be specified in manufacturing documentation.

5.2.2 In terms of appearance (defects), FRP bar must comply with requirements listed in the table 5.

Table 5

Defect name	Norm of restriction
Fissures	Not allowed
Spalling	Not allowed
Blisters	Not allowed
Protruding burrs with winding rush	Not allowed
Pinchers from mechanical effect with fibres damage	Not allowed

5.3 Requirements to raw material and materials

5.3.1 Materials used for production of FRP bars, must conform to the requirements of regulatory documents and technical documentation, have in-line documentation approving their compliance with the requirements of these regulatory documents and technical documentation, including test reports.

5.4 Marking

5 4.1 Production packing must have legible, easy-to-read marking.

5.4.2 Marking is implemented by way of labels.

5.4.3 Marking is applied to label by print method.

5.4.4 Each package must be fastened by label. Method and place of fastening must be specified in manufacturer's documents.

5.4.5 Position of label must provide for unequivocal visual identification of production without damaging its package.

5.4.6 Marking must be kept during the whole service life when storage, transportation and handling operations.

5.4.7 Marking of FRP bar must contain the following data:

- name;
- name of country of origin;
- name of manufacturer;
- legal address of manufacturer;
- trademark (brand) of manufacturer;
- major application properties and/or characteristics;
- information on certification;
- serial number and production date;
- composition (package contents);
- symbol;
- number of products in packing unit;
- total length in packing unit;
- stamp of quality inspector and signature of packer;
- designation of standard and/or technical condition according to which it is produced and identified;
- bar code;
- transport marking as per GOST Standard 14192 with applying of handling mark "Keep dry".

Note — When marking of FRP bar you must comply with statutory regulations existing in each of member states of a treaty and establishing the procedure of product labelling with information in state language.

5.5 Package

5.5.1 Package must provide integrity of FRP bar during handling procedures, storage and transportation.

5.5.2 FRP bars of one lot with specific cut length are packed into bunches, it is allowed to be packed into hanks or drums for 4.8 as agreed upon with consumer.

5.5.3 FRP bars with specific cut length must be closely packed and firmly tied in cross

direction every other 1—1.5 m, at that distance between outside locations of bandaging from butts must be 10—20 cm.

5.5.4 Hanks must be tied around two binders located diametrically, and bunches of hanks must be firmly fastened by two-three binders.

5.5.5 Binding is carried out by strings as per GOST Standard 17308 or bands as per GOST Standard 3560.

5.5.6 During hand loading and unloading, mass of bunch, hank or drum, as well as mass of unpacked bars of FRP bars must not exceed 80 kg.

5.5.7 Mass of bunch, hank or drum during mechanized handling operations is regulated by type and specifications of lifting gears at manufacturer and consumers. Hand unloading is stipulated in order.

6 Safety and environmental requirements

6.1 FRP bar, under normal conditions of operation, during storage and transportation in accordance with requirements of section 9, must not emit harmful and toxic agents in concentrations, which are dangerous to human health and adversely affect environment.

6.2 FRP bar according to hygienic requirements [1] must comply with the table 6.

6.3 Production of FRP bar must be performed in conditions corresponding to [2] and [3].

6.4 Control over harmful production factors in conditions of production and hygienic indices of final product must be carried out according to production control programme approved at manufacturer according to [4] and [5].

6.5 When applying FRP bar you must comply with environmental requirements of GOST 17.2.3.02.

Table 6

Indicator name	Indicator meaning
Smell level, not less	2 points
Percent volatiles in air by [6], not more: - phenol - formaldehyde - toluene	 0.003 mg/m3 0.003 mg/m3 0.600 mg/m3
Effective specific activity of natural radioactive nuclides Aeff by[7], not more	370 Bq/kg

6.6 Waste recovery and disposal of FRP bar is carried out in accordance with current legislation in the field of environmental protection. Safety requirements and environment control measures must be specified in manufacturer's documents.

6.7 Manufacturer's documents of FRP bar must contain fire/explosion hazards as per GOST Standard 12.1.044, whereby transportation terms and conditions are scheduled.

7 Acceptance rules

7.1 FRP bar is accepted by lots pursuant to the requirements of this standard. A lot must contain FRP bar of one composition and dimension type, made of material of the same brand, by the same regulatory documents, on the same processing line, by permissible operational shutdowns not more than 3 h. Lot size is determined in regulatory documents of manufacturer.

7.2 Each FRP bar lot must be accompanied with passport (see appendix I).

7.3 FRP bar must be accepted upon quality by technical control service of manufacturer, at that the following types of production control must be provided for as per GOST Standard 16504:

- incoming control — quality of raw materials, from which FRP bar is produced, their regulatory compliance, on which these materials are manufactured, as well as compliance with process regulation;

- operational control – parameters of equipment performance and manufacturing process flow, fibre-reinforced plastic bar (FRP bar) parameters and their compliance with the process procedures;

- acceptance inspection – FRP bar quantity and quality indicators established by the present standard.

7.4 For the purposes of verification of FRP bar compliance with the requirements of the present standard the following tests shall be carried out as per GOST 16504:

- acceptance testing;
- periodic testing;
- routine testing.

7.5 Acceptance testing shall be performed for each batch.

7.6 Periodic testing shall be performed after 6 months from the date of the last periodic testing (during the first year of manufacturing) and after one year from the date of the last periodic testing (during subsequent years of manufacturing).

For the purposes of periodic testing, they shall take from the batch the FRP bar complying with the requirements of the present standard according to the results of manufacturing inspections and acceptance testing.

7.7 The results of periodic testing apply to all batches of FRP bar manufactured during the period between two successive periodic tests.

7.8 The results of acceptance testing and periodic testing aimed at evaluation of FRP bar indicators shall be represented in the Certificate.

7.9 Routing testing shall be carried out:

- when raw materials are changed;
- when amendments are introduced to regulatory documents for any raw material;
- when manufacturing process flow is changed;
- upon the customer's request in the process of certification.

7.10 The scope of control for every type of testing is given in the table 7.

7.11 Qualification testing shall be performed in the process of FRP bar manufacturing at new facilities or on new equipment according to all the indicators mentioned in the table 7 minimum on the first three batches.

7.12 When unsatisfactory testing results are obtained upon any indicator, repeated testing shall be performed upon this indicator using double quantity of specimens. When unsatisfactory testing results are obtained repeatedly the batch shall be discarded, FRP bar manufacturing process shall be stopped. After that, they shall carry out the analysis of the causes, which have led to unsatisfactory results and develop plan of the actions aimed at these causes elimination. Trial batch shall be manufactured for carrying out of acceptance testing and periodic testing in full extent upon the indicators which has given negative results. When satisfactory testing results are obtained on the trial batch the goods manufacturing is resumed. When unsatisfactory testing results are obtained on the trial batch, it is necessary to continue searching of the causes of defects until testing results complying with the requirements of the present standard are not obtained.

7.13 FRP bar manufacturer shall ensure complying with the requirements given in the items 5.1.3 – 5.1.4 with minimum confidence coefficient 95% and shall ensure annual confirmation of compliance with these requirements based on the results of the statistical analysis of acceptance testing and periodic testing obtained during the whole period of manufacturing.

Table 7

Test item	Test type			Scope of sampling from the batch
	acceptance	periodic	routine	
Appearance	+	-	+	Minimum 10%
Geometric dimensions: - outside diameter d_o - nominal diameter, d - length l	 + + +	 - - -	 + + +	Minimum 3 pcs. for acceptance testing, minimum 6 pcs. for periodic and routine testing
Ultimate strength limit σ_B	+	-	+	

Elastic modulus E_t	+	-	+	Minimum 3 pcs. for acceptance testing, minimum 6 pcs. for periodic and routine testing
Compressive strength σ_{ac}	-	+	+	
Cross-shearing strength τ_{sh}	-	+	+	
Strength of adhesion to concrete τ_r	-	+	+	
Reduction of ultimate strength limit after curing in alkaline medium, $\Delta\sigma_R$	-	+	+	
Adhesion to concrete after curing in alkaline medium τ_r	-	+	+	
Ultimate service temperature	-	+	+	

7.14 When manufacturing process stability is evaluated, compliance of FRP bar indicators with the required values is determined based on the results obtained for the period not exceeding 6 months. Criteria of FRP bar indicators compliance with the required values for manufacturing process stability evaluation are given in the table 8.

7.15 FRP bar compliance with the required indicators shall be determined by means of the calculation of the number of testing results obtained for evaluation period which are outside the limits of the required values, and by comparison of this number with the acceptance number.

7.16 FRP bar compliance with actually required value is confirmed when the number of testing results outside the limits of the required values does not exceed the acceptance number.

Table 8

Number of tests	Acceptance number
1-6	1
13-19	2
20-29	3
30-39	4
40-49	5
50-64	6
65-79	7
80-94	8
95-100	10

8 Control methods

8.1 FRP bar surface appearance and quality shall be inspected visually as for compliance with the established requirements or reference specimen without using any special magnifying devices.

8.2 Outside diameter, die-rolled section height, die-rolled section pitch of FRP bar shall be checked using beam-compass as per GOST 166 and using micrometer as per GOST 6507.

8.3 FRP bar length shall be checked using ruler as per GOST 427, using measuring tape as per GOST 7502 having nominal scale length 10, 20 m, third class of accuracy.

8.4 Nominal diameter shall be determined as per GOST 15139 as supplemented (see Annex A).

8.5 Mechanical properties at axial tension shall be determined as per GOST 12004 as amended and supplemented (see Annex B).

8.6 Compression strength shall be determined as per GOST 4651 as amended and supplemented (see Annex C).

8.7 Cross-shearing strength shall be determined according to the Annex D.

8.8 Strength of adhesion to concrete shall be determined according to the Annex E.

8.9 Resistance to alkali medium of concrete shall be determined according to the Annex F.

8.10 Ultimate service temperature shall be determined according to the Annex F.

8.11 Effective specific activity of natural radioactive nuclides of raw materials used for FRP bar manufacturing shall be determined as per GOST 30108.

9 Shipping and storage

9.1 FRP bars shall be shipped in horizontal position in any vehicle according to the shipping rules effective for the certain type of vehicle with adherence to the storage requirements.

9.2 FRP bars shall be stored in horizontal position on a rack in unheated or heated warehouses at the distance not less than 1 m from heating devices at the minimum height from the floor of 100 mm.

9.3 During storage, shipping and handling one shall consider the measures preventing mechanical damage of FRP bars, effects of ultraviolet radiation and moisture.

10. Manufacturer guarantees

10.1 The manufacturer guarantees FRP bars compliance with the requirements of the present standard provided that customer considers requirements and regulations on storage, shipping and usage.

10.2 Guarantee period for FRP bars storage – 24 months from the date of manufacturing.

10.3 Upon expiration of the guarantee storage period FRP bars could be used only after its testing for absolute compliance with the requirements of the present standard.

Annex A
(reference)

Method for Determination of Nominal Diameter

A.1 General

The present method is based upon determination (based on the results of hydrostatic weighing) of the volume of the specimen cut from the inspected item with the specified length and subsequent calculation of nominal diameter.

A.2 Specimens

A.2.1 Test specimens are taken by the method of random selection from the inspected batch of FRP bars. It is required that this process is documented in the sampling certificate containing the following information:

- name of the manufacturing company;
- identification code;
- type of fiber and binding substance;
- date of manufacturing;
- batch number;
- quantity and dimensions of specimens;
- indicators to be inspected using the taken specimens;
- signature of the person responsible for sampling.

A.2.2 In the process of FRP bars specimens selection and preparation for testing it is necessary to exclude deformation and heating, the effects of ultraviolet radiation and other environmental impacts which can cause changes of the material properties.

A.2.3 Number of specimens taken for testing shall comply with the requirements of the table 7.

A.2.4 Measured fragments used as testing specimens shall have the length l, mm, determined by the formula:

$$l \geq 10\ l_{np} \qquad (A.1)$$

where l_{np} – is length of die-rolled section pitch, mm.

A.2.5 Before testing the test specimens shall be cured according to the requirements of GOST 12423.

A.3 Equipment and materials

The following equipment and materials are used for the testing:

- analytical balances, minimum 2d accuracy class;
- vessel and fixing (clamps) for hydrostatic weighing to analytical balances;
- beam-compass as per GOST 166, maximum scale division – 0.1 mm.

A.4 Conduction of testing

A.4.1 Testing conditions shall comply with the section 3.15 of GOST 15150.

A.4.2 The length of every specimen shall be measured 3 times while rotating the specimen by the angle of 120° after each measurement. The average value of three measurements shall be rounded to 0.1 mm. The length of a specimen shall be measured with the tolerance of not more than 0.1 mm.

A.4.3 The vessel for hydrostatic weighing shall be filled with distilled water, left at a room temperature for 2 hours.

A.4.4 The clamps without specimen shall be immersed into the vessel filled with water, the indications of the balances shall be zeroed or recorded.

A.4.5 The specimen shall be fixed in the clamps and the balances reading m_1 shall be recorded. Then the specimen together with the clamps shall be immersed into the water and balances reading m_2 shall be recorded.

A.5 Processing of the testing results

Nominal diameter *d*, mm, shall be calculated by the formula:

$$d = \sqrt{\frac{4(m_1 - m_2)}{\pi \rho l}}, \quad \text{(A.2)}$$

where m_1 – weight of a specimen in the air, mg;

m_2 – weight of a specimen in the water, mg;

ρ – water density, mg/mm^3 (taken as ρ = 1);

l – length of a specimen, mm.

The values of the evaluated characteristics and quantities used for intermediate calculations shall be determined with the relative accuracy of not less than 0.01 (1%).

Statistical processing of the testing results shall be performed according to the requirements of GOST 8.207.

A.6 Test report

Test report shall contain the following:

- the information about the specimens given in the sampling certificate;
- name of the company conducting the testing;
- date of testing;
- the information about testing conditions;
- the values of the measured parameters for every specimen;
- the values of the determined characteristics for every specimen obtained in the process of the testing results processing;
- the average values, standard deviation of the determined characteristics and the results of testing results statistical processing;
- the information about the specialists who have conducted testing and their signatures.

Annex B
(reference)

Axial tension test method

B.1 General

The present method establishes requirements for axial tension testing of FRP bar for the purposes of determination of the following properties:

- strength limit;
- elastic modulus;
- percentage elongation;

The method establishes the following requirements for axial tension testing of FRP bar:

- specimen destruction shall occur within the limits of the operating zone;
- the part of a specimen located between testing sleeves used for specimen clutching within the grips of testing machine is considered as the operating zone;
- the effect of shearing load and radial tensile load occurring in the intermediate zone from the testing sleeve to the bar on the process of specimen destruction shall not be taken into consideration.

B.2 Specimens

B.2.1 Test specimens are taken by the method of random selection from the inspected batch of FRP bar. It is required that this process is documented in the sampling certificate containing the following information:

- name of the manufacturing company;
- identification code;
- type of fiber and binding substance;
- date of manufacturing;
- batch number;
- quantity and dimensions of specimens;
- indicators to be inspected using the taken specimens;
- signature of the person responsible for sampling.

In the process of selection of FRP bar specimens and preparation for testing it is necessary to exclude deformation and heating, the effects of ultraviolet radiation and other environmental impacts which can cause changes of the material properties.

Number of specimens taken for testing shall comply with the requirements of the table 7.

B.2.2 The length of testing sleeves shall be determined based on the conditions ensuring specimen rupturing within the length of the operating zone without slipping in testing sleeves.

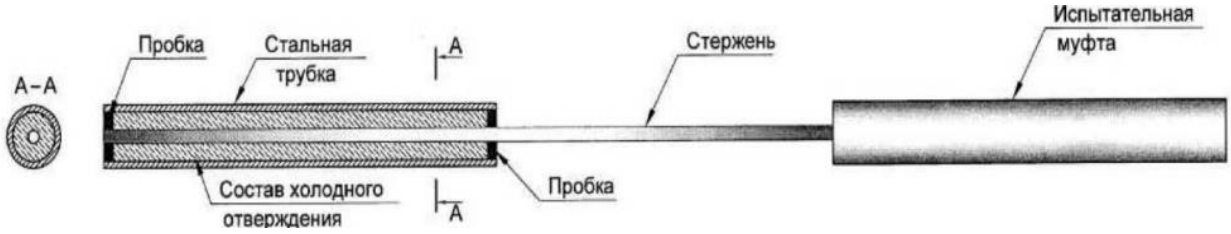
B.2.3 Length of test specimen s is determined by the length of the operating zone and the length of two testing sleeves.

The recommended structure and dimensions of testing sleeve are given in the figure B.1 and the table B.1.

The length of the operating zone shall be minimum 40*d* of the bar.

B.2.4 It is permitted to use shorter specimens provided that the rupture occurs within the length of the operating zone without slipping in testing sleeves.

B.2.5 Before testing test specimens shall be cured according to the requirements of GOST 12423.



Пробка	Plug
Стальная трубка	Steel pipe
Стержень	Bar
Испытательная муфта	Testing sleeve
Состав холодного отверждения	Cold curing compound

Figure B.1 – Pattern of the standard test specimen

Table B.1 – Dimensions of test specimens and testing sleeves, mm

FRP bar nominal diameter	Testing sleeve		
	Outside diameter	Minimum length	Wall thickness
From 4 to 10	35	300	From 3 to 5
» 12 » 16	42	350	
» 18 » 22	48	450	
» 22 » 30	60	500	

B.3 Equipment and materials

B.3.1 Testing machine as per GOST 28840 shall ensure:

- that load exceeds specimen strength during testing for the indicator being verified;
- change of load and distance between cross-beams with a tolerance of not less than 0.5 %;
- the displacement velocity of active cross-beam within the range from 5 to 100 mm/min.

B.3.2 Data recording system shall provide continuous recording of load, strain and displacement. Minimum recorded value shall amount:

- for load ..... 100 N;
- for strain ..... 0.01 mm;
- for displacement ..... 0.001 mm.

B3.3 Extensometers or linear displacement transducers shall be used as strain gauges. These devices shall record elongation of a specimen during testing with minimum accuracy of 0.002 % from the length of the section between the transducers.

B.4 Conduction of testing

B.4.1 Testing conditions shall comply with the section 3.15 of GOST 15150.

B.4.2 When a specimen is positioned on the testing machine it is necessary to monitor the accuracy of the specimen longitudinal axis coincidence with the connection line of two testing sleeves.

B.4.3 Extensometers or linear displacement transducers shall be installed in the middle of the operating zone at the distance of not less than 8*d* of the bar from the testing sleeve, at the same time the gauge length for measuring of ultimate strain shall be not less than 8*d* of the bar.

B.4.4 Supposed maximum load *P*, N, shall be determined based on the results of the pilot testing of pilot specimen.

B.4.5 Data recording system shall be turned on a few seconds before start of load applying. In the process of testing rate of load applying shall be constant and shall ensure specimen rupturing within the period from 3 to 10 minutes.

B.4.6 The strain shall be recorded to the load level amounting not less than 50% from the ultimate strength limit.

If specimen rupture occurs in the testing sleeve or if a specimen slips out of the sleeve it is required to conduct additional testing of a specimen taken from the same batch.

“Load-d” diagram shall be built based on the measurements of load and strain recorded by extensometers.

B.5 Processing of the testing results

B.5.1 Strength limit σ_B, MPa, shall be determined by the formula:

$$\sigma_B = \frac{P}{A}, \quad \text{(B.1)}$$

where P – rupture load, N;

A – cross-section area of the bar $A = \pi d^2/4$, mm^2.

B.5.2 The value of initial tangent modulus of elasticity E_f, MPa, is calculated as a ratio of load increment during tension within the range from 0.23P to 0.5P and strains by the formula:

$$E_f = \frac{P_1 - P_2}{(\varepsilon_1 - \varepsilon_2)A}, \quad \text{(B.2)}$$

where P_1 – load amounting (50 ± 2) % of the rupture load, N;

P_2 – load amounting (20 ± 2) % of the rupture load, N;

ε_1 – strain corresponding to the load P_1;

ε_2 – strain corresponding to the load P_2.

B.5.3 Relative elongation under rupture load ε_ε, mm/mm, is calculated by the formula:

$$\varepsilon_\varepsilon = \frac{P}{E_l A}, \quad \text{(B.3)}$$

The values of the evaluated characteristics and quantities shall be determined with the accuracy of up to 0.001.

Statistical processing of the testing results shall be performed according to the requirements of GOST 8.207.

B.6 Test report

Test report shall contain the following:

- the information about the specimens given in the sampling certificate;
- name of the company conducting the testing;
- date of testing;
- the information about testing conditions;
- geometric characteristics of each specimen;
- the values of the measured characteristics for every specimen;
- the values of the determined characteristics for every specimen obtained in the process of the testing results processing;
- the average values, standard deviation of the determined characteristics and the results of testing results statistical processing;
- "load-strain" diagram for every specimen;
- the information about the specialists who have conducted testing and their signatures.

Annex C
(reference)

Compression test method

C.1 General

The present method establishes requirements for compression testing of FRP bars for the purposes of determination of compression strength.

The method is based on specimen rupturing by application of axial compression load.

The method considers main provisions of GOST 4651 as amended and supplemented:

- rupture of pilot specimen shall occur within the operating zone;
- the part of a specimen located between testing sleeves used is considered as the operating zone;
- the effect of shearing load and radial tensile load occurring in the intermediate zone from the testing sleeve to the bar on the process of specimen destruction shall not be taken into consideration.

C.2 Specimens

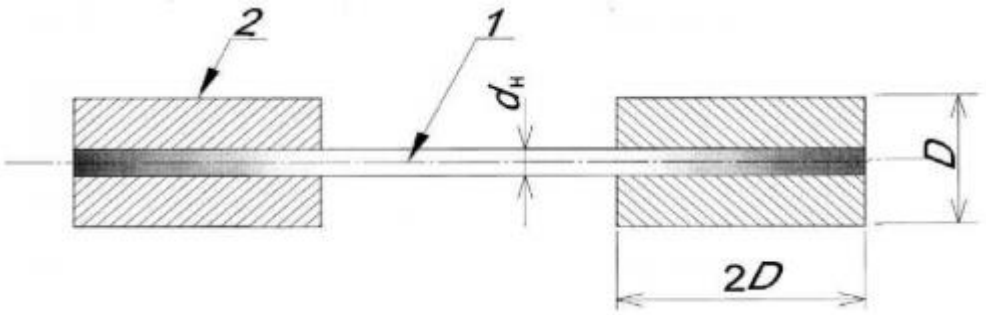
C.2.1 Test specimens are taken by the method of random selection from the inspected batch of FRP bars. It is required that this process is documented in the sampling certificate containing the following information:

- name of the manufacturing company;
- identification code;
- type of fiber and binding substance;
- date of manufacturing;
- batch number;
- quantity and dimensions of specimens;
- indicators to be inspected using the taken specimens;
- signature of the person responsible for sampling.

In the process of FRP bar specimens selection and preparation for testing it is necessary to exclude deformation and heating, the effects of ultraviolet radiation and other environmental impacts which can cause changes of the material properties.

Number of specimens taken for testing shall comply with the requirements of the table 7.

C.2.2 Test specimen (see figure C.1) consists of the section of the bar at the ends of which testing sleeves are mounted on glue line.



1- the section of the bar; *2* – testing sleeve

Figure C.1 – Schematic diagram of test specimen

C.2.3 Total length of a specimen is determined by bush construction.

C.2.4 Length of the bar operating zone located between bushes shall amount 6*d*.

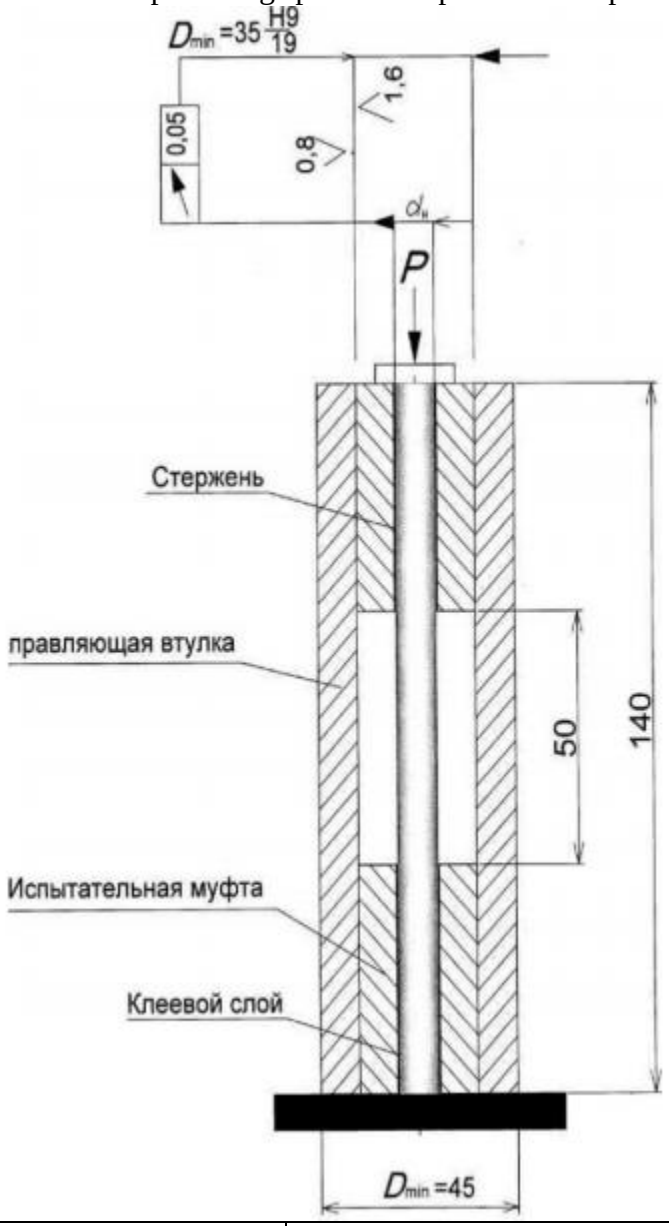
C.2.5 Before testing the specimens shall be cured according to the requirements of GOST 12423.

C.3 Equipment and materials

C.3.1 Testing machine as per GOST 28840 shall ensure:

- that load exceeds specimen strength during testing for the indicator being verified;
- change of load and distance between cross-beams with a tolerance of not less than 0.5 %;
- the displacement velocity of active cross-beam within the range from 5 to 100 mm/min.

C.3.2 The device for specimens compression testing (see figure C.2) consists of the guide bush providing possibility of the load appliance strictly along the bar axis, and two testing sleeves, installed at the both ends and providing specimen rupture in the operation zone.



Стержень	Bar
Направляющая втулка	Guide bush
Испытательная муфта	Testing sleeve
Клеевой слой	Glue line

Figure C.2 – Device for specimens compression testing

C.4 Conduction of testing

C.4.1 Testing conditions shall comply with the section 3.15 of GOST 15150.

C.4.2 A specimen is positioned in the testing machine.

C.4.3 The measuring system is turned on and the drive of the testing machine is switched to the test mode. The recommended velocity value lays within the range from 5 to 15 mm/min. The load shall be applied gradually; a specimen shall not be subjected to impacts.

C.4.4. Applying of load shall be continued until a specimen is ruptured. If a specimen rupture occurs outside the limits of the operating zone it is required to conduct additional testing of a specimen taken from the same batch.

C.4.5 Rupture load is determined with the accuracy of up to 0.001.

C.5 Processing of the testing results

C.5.1 Compressive strength σ_{BC}, MPa, shall be determined by the formula:

$$\sigma_{BC} = \frac{4P}{\pi d^2}, \quad \text{(C.1)}$$

where P – rupture load, N;

d – nominal diameter, mm.

The values of the evaluated characteristics and quantities shall be determined with the accuracy of up to 0.001.

Statistical processing of the testing results shall be performed according to the requirements of GOST 8.207.

C.6 Test report

Test report shall contain the following:

- the information about the specimens given in the sampling certificate;
- name of the company conducting the testing;
- date of testing;
- the information about testing conditions;
- geometric characteristics of each specimen;
- test results;
- the values of the measured characteristics for every specimen;
- the values of the determined characteristics for every specimen obtained in the process of the testing results processing;
- the average values, standard deviation of the determined characteristics and the results of testing results statistical processing;
- the information about the specialists who have conducted testing and their signatures.

Annex D
(reference)

Transverse shear strength test method

D.1 General provisions

The present test method sets the requirements to testing FRP bars on the basis of determining the value of maximal shear strength at shearing of the bar in the transverse direction with regard to the fibers.

The method is based on loading the specimen with the shearing strength by means of direct applying of the double shear

D.2 Test specimens

D.2.1 Test specimens are selected randomly from the controlled lot of FRP with mandatory formalization of the selection procedure by issuing the specimens sampling protocol, which should include:

- name of the manufacturing company;
- designation marks;
- type of the fiber and bonding substance used;
- date of production;
- lot number;
- number and size of specimens;
- parameters that should be tested on selected specimens;
- signature of the person responsible for the sampling procedure

While sampling and preparation of specimens there should be avoided any and all deformation, heating, exposure to ultraviolet light and other environmental effects that might cause changes to material properties.

The number of specimens selected for testing must comply with the requirements set out in Table 7.

D.2.2 A selected for testing specimen represents a bar, the length of which is determined based on the testing machine design, but not less than 250 mm irrespective of the specimen diameter

D.2.3 Before performance of testing the specimens should be cured according to the requirements set out in the provisions of GOST 12423.

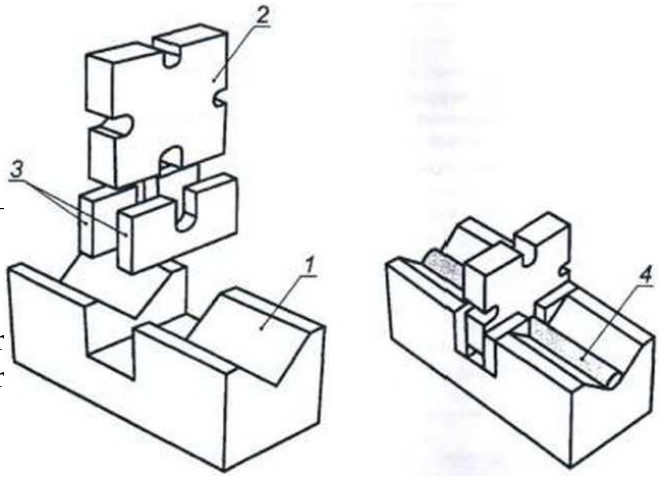
D.3 Testing equipment and materials

D.3.1 According to the provisions of GOST 28840 the testing machine should provide for:

- loading capacity in excess of the tensile capacity of the specimen when performing testing for the controlled parameter;
- measurements of loading capacity and the distance between the transverse shears with the error of not more than 0.5%.
- the active transverse shear displacement speed should be within the rate of 5 to 100 mm per minute.

D.3.2 The testing machine used for performance of tests must consist of the specimen holder with a longitudinal V-shaped groove (see Figure D.1), a rectangular-shaped groove for fixture of the upper and lower blades with the V-shaped grooves or the holes to run through (see Figure D.2) for mounting of the specimens calibrated in compliance with their diameter.

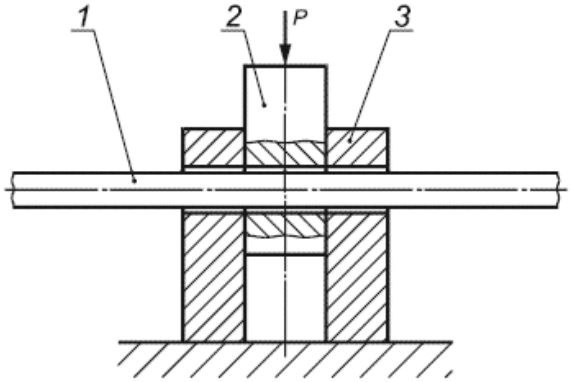
D.3.3 The total sum of two gaps between one upper blade and two lower blades should be not less than 0.25 mm.



b) Element by element a) Assembled

1 — Test specimen holder; *2* — upper blade;
3 — lower blades; *4* — specimen

Figure D.1 — Apparatus for testing the specimens for transverse shear strength.



1 — specimen; *2* — upper blade; *3* — lower blades.

Figure D.2 — Installation diagram of the test apparatus with the holes to run through

D.4 Performance of tests

D.4.1 The testing conditions should comply with the requirements of subparagraph 3.15 GOST 15150.

D.4.2 The specimen should be inserted into the center of the test apparatus and installed in the testing machine.

D.4.3 The surface of upper blade should contact with the loading device of the testing machine. No gap is admissible.

D.4.4 The measuring appliance and the drive of the testing machine are switched on into the testing mode. The loading rate shall be such that the shearing stress amounts from 5 to 15 mm per minute. The loading should be applied uniformly without subjecting the specimen to shocks.

D.4.5 The specimen should be cut by blade edges in two planes simultaneously converging along the faces perpendicular to its axis.

D.4.6 To decrease friction of the blade edges their surfaces are to be grinded, polished or covered with a thin lubrication coating.

D.4.7 The loading should be applied until the failure of the specimen.

D 4 8 The shear failure load should be determined with the accuracy of up to 0.001.

D.4.9 While performing the test vertical displacements of the bar are measured with the

accuracy of up to 0.01 mm with the help of the electronic meter used for measuring the displacement of the hydraulic press slabs.

D.5 Processing of test results

The maximally allowable shear strength τ_{sh}, MPa is calculated according to the formula:

$$\tau_{sh} = \frac{P}{2A} \quad \text{(D.1)}$$

where P is the shear failure load, N;

A is the nominal cross-sectional area of the specimen. $A = \pi d^2/4$. mm^2

Statistical processing of the test results shall be performed compliant to the requirements of GOST 8.207.

D.6 Test protocol

The test protocol shall include the following items:

- information about the specimens, as provided in the specimens sampling protocol;
- name of the testing facility that performed the testing;
- date of performance of testing;
- information about the conditions for performance of testing;
- geometrical characteristics of each specimen;
- results of the tests;
- values of measured characteristics for each of the tested specimen:
- values of the characteristics determined for each of the specimens, which were obtained at processing of the results of the tests;
- average values of the determined characteristics and the results of statistical processing of the obtained results;
- type and manner of shear failure for each specimen;
- personal data of the experts engaged in performing the testing and their signatures.

Annex E
(reference)

Test of limit bond strength to concrete

E.1 General provisions

The present test method sets the requirements to performance of testing for bond strength between the FRP bars and concrete by means of axial pull-out of the reinforcement bar from the concrete cube or for bending tensile capacity of the bar.

The method is based on determining the values of displacement tensile stress along the boundary of FRP bonding with the concrete realized at the maximum load applied and obtained at the maximum load resulting in pull-out elongation of the specimen before its load failure, irrespective of the place where the specimen failure occurs (whether along the bar length or along the boundary of the bar bonding with the concrete).

E.2 Test specimens

E.2.1 Test specimens are selected randomly from the controlled lot of FRP bars with mandatory formalization of the selection procedure by issuing the specimens sampling protocol, which should include:

- name of the manufacturing company;
- designation marks;
- type of the fiber and bonding substance used;
- date of production;
- lot number;
- number and size of specimens;
- parameters that should be tested on selected specimens;
- signature of the person responsible for the sampling procedure

While sampling and preparation of specimens there should be avoided any and all deformation, heating, exposure to ultraviolet light and other environmental effects that might cause changes to material properties.

The number of specimens selected for testing must comply with the requirements set out in Table 7.

E.2.2 The specimens for testing the bond strength by means of axial pull-out of the bar from the concrete cube consist of concrete cubes, in the centers of which there are vertically installed bar-shaped FRP bars with the testing sleeve perpendicular or in parallel to the direction of concrete layer (see Figure E.1). the dimensions of concrete cubes depending upon the FRP bar diameters are provided in Table E.1.

Total length of the specimen to be tested is determined by the following factors:

- conditions of installation and fitting into the concrete cube;
- conditions of mounting of the specimen in the testing machine;
- design of the testing sleeve.

Table E.1 — Dimensions of the specimens, mm

Nominal diameter of the FRP bar	Size of the concrete cube edge	FRP bar-to-concrete bonded length
≤10	100	5 *d*
12 to 18	150	
20 to 30	200	

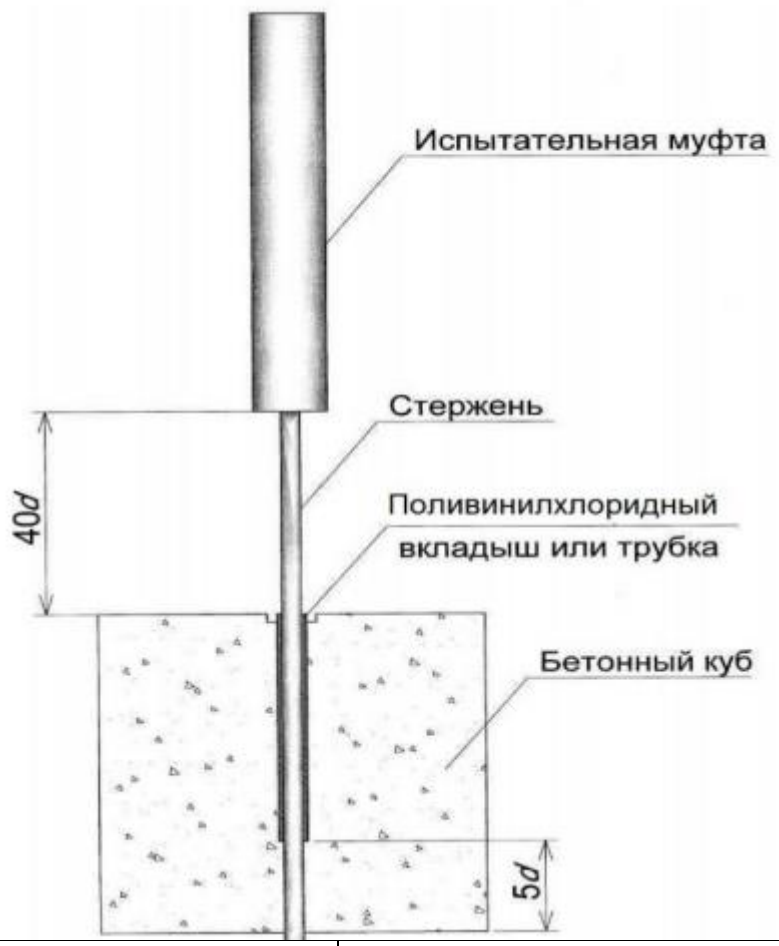
E.2.3 Part of the FRP bar bonded into concrete should be sheathed by a polyvinylchloride

insert or tube.

E.2.4 The surface of the specimen with the vertically mounted FRP bar by a square steel plate with the side length of not less than 200 mm and the thickness of 20 mm, which should be used as the load bearing surface during the testing procedure and exclude applying strength to the concrete cube. The plate shall have a hole in its center through which the FRP bar of the appropriate diameter should pass.

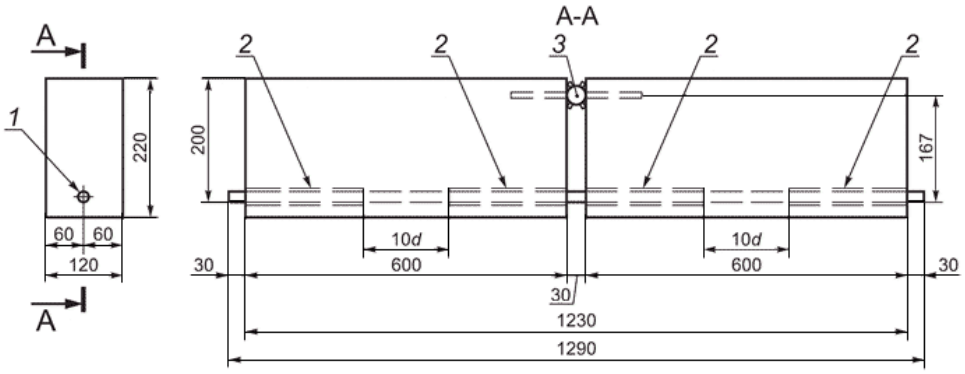
E.2.5 The specimens used for testing the bending tensile capacity of the bar (see Figure E 2) consist of two halves joined together by the tested FRP bar in the tension area, and by a knuckle joint formed by two block-outs with a steel cylinder between them – in the compression area. In the center of each of the halves FRP bar shall have a bonding area equal to 10*d*, the half edges outside of the bonding area shall be sheathed by the polyvinylchloride tube.

The specimens should have the rectangular cross-section of 120 x 220 mm. the length of 1230 mm, the length of the halves of 500 mm each, and the gap between the halves of the bar of 30 mm. The distance from the axis of the tested FRP bar to the axis of the steel cylinder should be equal to 167 mm in the compression area.



Испытательная муфта	Testing sleeve
Стержень	Bar
Поливиниловый вкладыш или трубка	PVS insert or tube
Бетонный куб	Concrete cube

Figure E.1 - Installation diagram of FRP bar mounting in the concrete cube



1 - bar; *2* - polyvinylchloride insert or tube; *3* – steel cylinder

Figure E.2 - Installation diagram of FRP bar mounting in the concrete while testing the bending tensile capacity of the bar

E.2.6 It is recommended the following mode of making up the concrete in the form:

- the concrete mix shall be placed in four layers of approximately equal thickness whereas each layer should be poked 25 times by a metal bar having the diameter of 16 mm;
- after puddling of the upper layer the surface should be smoothed and cleaned from moisture evaporations, including the bonding section of the vertically mounted FRP bar.

E.2.7 The requirements set to the concrete quality shall be the following:

- maximum dimensions of coarse aggregates 20 to 25 mm;
- mobility of concrete mix, grade P3;
- concrete compressive strength, grade B25.

E.2.8 The compressive strength of the concrete shall be determined on the basis of the concrete cubes having the edge size of 100 mm whereas at least three specimens are tested. Removal of forms from the test shall be performed not earlier than 24 hours after their manufacturing. The specimens shall be stored under normal conditions. The age of the test specimens used for testing shall be 28 days.

E.2.9 Before performance of testing the specimens should be cured according to the requirements set out in GOST 12423.

E.3 Testing equipment and materials

E.3.1 According to the provisions of GOST 28840 the testing machine should provide for:

- loading capacity in excess of the tensile capacity of the specimen when performing testing for the controlled parameter;
- measurements of loading capacity and the distance between the transverse shears with the error of not more than 0.5%;
- the active transverse shear displacement speed should be within the rate of 5 to 100 mm per minute.

E.3.2 To measure slippage of the FRP bar from the concrete there should be applied strain gauges, linear variable differential transformers, and analog or digital display sensors with the accuracy of up to 0.01 mm (the devices for measuring slippage).

E.3.3 To prepare the specimens there should be required:

- metal forms for manufacturing concrete cubes and the loading plates having holes for mounting the bar-shaped FRP bar of the appropriate diameter. The loading plates have to be waterproof and easily removable without causing any damage to

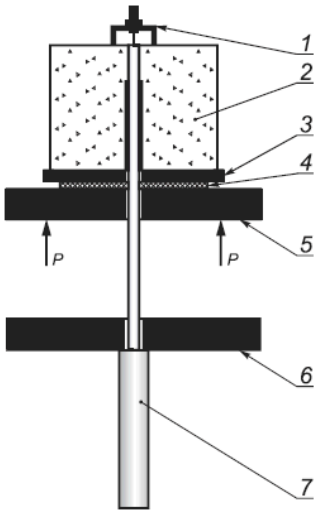
the FRP bars;

– anchorage sections in compliance with the requirements of Table 5.1 Annex B.

E.4 Performance of tests

E 4.1 The testing conditions should comply with the requirements of subparagraph 3.15 GOST 15150.

E.4.2 The specimen used for performance of bond strength test by means of axial pull-out of the reinforcement bar from the concrete cube shall be mounted in a manner that the loading plate of the concrete cube, from which the free end of the FRP bar shall protrude, should contact via the soft gasket with the moving transverse shear of the testing machine (see Figure E.3).



1 – slippage measuring device at the free end of the bar*; 2* – specimen; *3* – loading plate; *4* – soft gasket; *5* – moving transverse shear of the testing machine; *6* - fixed transverse shear of the testing machine; *7* – anchorage section.

Figure E.3 — Installation diagram of mounting the specimen at axial pull-out from the concrete cube

E.4.3 The load-transmission device shall rest on the support transmitting the load to the force-measuring device of the testing machine.

E.4.4 The protruding bar shall pass through the node of the load-transmission device and the loading plate while the testing sleeve shall be mounted via the fixed transverse shear or in the holders of the testing machine.

E.4.5 The device for measuring slippage shall be installed on the free end of the FRP bar.

E.4.6 the distance between the upper surface of the fixed transverse shear or the holders of the testing machine to the surface where the device for measuring slippage is installed, shall be measured with the accuracy of up to ±0.01 mm.

E.4 7 When the bar has undergone a failure or has slipped out of the testing sleeve before it slips form the concrete, or the applied load is significantly reduced due cracking of the concrete, then the measurement data are rejected and the tests are repeated using an additional specimen from the same lot.

E.4.8 If splitting of the concrete occurs as the result of testing, then it is required to increase the size of the edge of the concrete tubes or apply for beam test.

E.4.9 Testing for bending tensile capacity of the bar shall be performed according to the method shown in Figure E.4. The slippage measuring device shall be installed on both end faces of the beam at the end of the bar.

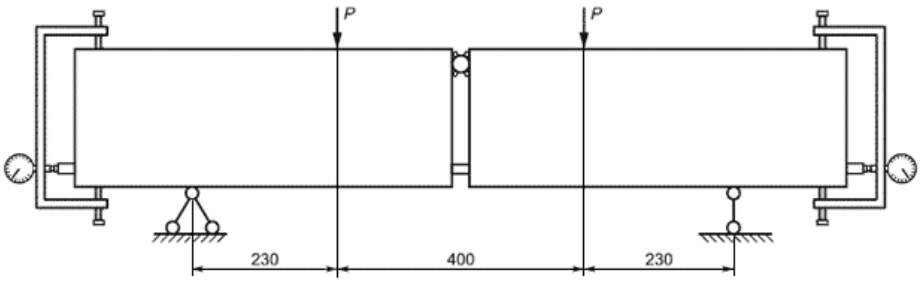


Figure E.4 - Installation diagram of testing the specimen for beam-test

E.4.10 Recording of the applied load and the readings of the slippage measuring device shall be performed in equal increments constituting 10 % of the anticipated load of the bar slippage for the value of 0.25 mm. At each increment of the load the specimens are cured during 15 seconds, and the readings of the slippage measuring devices are taken during that time. Then the test specimen is loaded until the bar failure or splitting or cracking of the concrete, or the bar slippage for the value of 0.25 mm, and the failure load and the slippage value are recorded with the accuracy of ± 0.01 mm.

E.4.11 The load shall be applied to the specimen at the rate of not more than 20 kN per minute.

E.5 Processing of test results

E.5.1 The curves of «bond stress versus slippage displacement» are plotted for each specimen.

E.5.2 Average values of bond stress causing slippage displacement on the free end of the FRP bar for 0.05, 0.10 and 0.25 mm and maximum values of bond stress are determined.

E.5.3 The FRP-to-concrete bond strength τ_r, MPa for testing by means of axial pull-out of the FRP bar from the concrete cube is calculated according to the formula:

$$\tau_r = \frac{P}{cL_{fb}} \qquad \text{(F.1)}$$

where P is the applied load, N;

u is the nominal peripheral length of the bar, $c = \pi d$, mm;

L_b is the length of the bar bonding with the concrete, mm.

E.5.4 At each increment of the applied load the value of slippage displacement on the free end of the bar is calculated as the difference between the readings of the slippage displacement measuring device and the value of elastic elongation of the bar.

E.5.5 The value of elastic elongation of the bar S, mm is determined according to the formula:

$$S = \frac{PL}{E_f A} \qquad \text{(F.2)}$$

where P is the applied load, N;

L is the length from the upper surface of the fixed transverse shear or in the holders of the testing machine to the place of installation of the device used for measuring the slippage displacement on the free end of the bar, mm;

E_f is the module of elasticity, MPa;

A is the nominal cross-sectional area of the specimen. $A = \pi d^2/4$. mm^2

E.5.6 The FRP-to-concrete bond strength τ_r, MPa for testing for bending tensile capacity of the bar is calculated according to the formula:

$$\tau_r = \frac{N_x}{A - z} \quad \text{(F.3)}$$

E.5.7 The axial force in the bar *N,* N in the middle of the beam is calculated according to the formula:

$$N_x = \frac{M}{z} \quad \text{(F.4)}$$

where *M* is the total momentum of the cross-section, which divides the beam in two halves, N • mm;

z is the arm of the internal pair of the cross-section dividing the beam in two halves, it is equal to the distance between the bar axis and the axis of the steel cylinder in the compression area, mm.

E.5.6 Test protocol

The test protocol shall include the following items:

- information about the specimens, as provided in the specimens sampling protocol;
- name of the testing facility that performed the testing;
- date of performance of testing;
- information about the conditions for performance of testing;
- geometrical characteristics of each specimen;
- information about the quality of the concrete: composition and mobility of the concrete mix, compressive strength of concrete tests pieces at the age of 28 days;
- information about the bars, as provided in the specimens sampling protocol – ultimate bond strength during pull-out testing and the value of the module of elasticity, dimensions of the specimens, bonded length of the bars mounting into the concrete;
- values of measured characteristics for each of the tested specimen:
- values of the characteristics determined for each of the specimens, which were obtained at processing of the results of the tests;
- average values of the determined characteristics and the results of statistical processing of the obtained results;
- type of load failure, curves of «bond stress versus slippage displacement» for each specimen;
- personal data of the experts engaged in performing the testing and their signatures.

Annex F
(reference)

Alkali resistance accelerated test method

F.1 General provisions

The present test method sets the requirements to estimation of alkali resistance of the FRP bars by means of their immersion into the alkaline aqueous solution under the conditions of the effect of the alkaline environment on the FRP bars with subsequent performance of tensile testing and bond stress testing.

F.2 Scope of the method

The method envisages performance of testing under two testing procedures:

- Procedure A is the procedure, under which the specimens are immersed into the alkaline aqueous solution with subsequent straining of them until the complete failure occurs. The controlled parameters include – the pH level, the temperature of the alkaline aqueous solution, and the immersion time;
- Procedure B is the procedure, under which the specimens, one end of which is fitted with the anchorage section for fitting the specimen in the testing machine, while the other is immersed into the alkaline aqueous solution and bonded with the concrete with subsequent pulling it out of the concrete. The controlled parameters include – the pH level, the temperature of the alkaline aqueous solution, and the immersion time.

F.3 Test specimens

F.3.1 Test specimens are selected randomly from the controlled lot of FRP bars with mandatory formalization of the selection procedure by issuing the specimens sampling protocol, which should include:

- name of the manufacturing company;
- designation marks;
- type of the fiber and bonding substance used;
- date of production;
- lot number;
- number and size of specimens;
- parameters that should be tested on selected specimens;
- signature of the person responsible for the sampling procedure

While sampling and preparation of specimens there should be avoided any and all deformation, heating, exposure to ultraviolet light and other environmental effects that might cause changes to material properties.

The number of specimens selected for testing must comply with the requirements set out in Table 7.

F.3.2 Total length of the specimens subject to testing under Procedure A shall comply with B.2.3 Annex B.

F.3.3 The specimens subject to testing under Procedure B shall comply with E.2.2 Annex E

F.3.4 The concrete mix shall be placed in accordance with the instructions set out in E 2.6 Annex E

F.3.5 The requirements set of the quality of concrete shall be in compliance with the provisions of E.2.7, E.2.8 Annex E

F.3.6 In order to prevent infiltration of the alkaline aqueous solution into the body of the bar, the end faces of the specimens subject to testing under Procedures A and B should be coated with a thin layer of epoxy resin.

F.3.7 The specimens shall be cured before performance of testing in accordance with the requirements set out in GOST 12423.

F.4 Testing equipment and materials

F.4.1 According to the provisions of GOST 28840 the testing machine should provide for:

- loading capacity in excess of the tensile capacity of the specimen when performing testing for the controlled parameter;
- measurements of loading capacity and the distance between the transverse shears with the error of not more than 0.5%;
- the active transverse shear displacement speed should be within the rate of 5 to 100 mm per minute.

F.4.2 The alkaline aqueous solution shall simulate the pore solution found in the concrete and be of the following composition: 8.0 g of NaOH and 22.4 g KOH in 1 l of deionized water.

F.4.3 The value of pH of the alkaline aqueous solution shall be within the limits of 12.6 to 13. Before and after the test the alkaline aqueous solution should be kept in a closed container to avoid its interaction with the CO_2 contained in the ambient air and evaporation.

F.4.4 The anchorage sections shall comply with the requirements set out in Table B.1 Annex B.

F.5 Performance of tests

F 5.1 The sequence of performance of testing under Procedure A shall be the following:

- before immersion into the alkaline aqueous solution the specimen should be dried till the constant mass m_0 at the temperature of (100 ±2) °C.
- the specimens shall be immersed into the alkaline aqueous solution with the constant temperature of (60 ± 3) °C for 30 days, at that, it is allowed to immerse into the alkaline aqueous solution not the entire specimen but only its tested part between the testing sleeves;
- after immersion the specimen should be removed from the alkaline aqueous solution, rinsed in deionized water, dried at the temperature of (100 ±2) °C within not less than 4 hours, and then weighed (m_1).
- the specimens shall be installed in the testing sleeves and tested for strength limit until complete failure pursuant to Annex B.

F.5.2 The sequence of performance of testing under Procedure B shall be the following:

- the specimens shall be immersed into the alkaline aqueous solution with the constant temperature of (60 ± 3) °C for 30 days, at that, it is allowed to immerse into the alkaline aqueous solution not the entire specimen but only its tested part bonded into the concrete;
- after immersion the specimen should be removed from the alkaline aqueous solution;
- one end of the specimen shall be installed in the testing sleeve designed for its fixing in the testing machine, the other end of the specimen (immersed in the alkaline solution) shall be mounted in the concrete in accordance with the provisions of E.2.3, E.2.4 Annex E;
- after 28 days of the concrete curing the specimen shall be installed in the testing machine under the procedure as shown in Figure E.3:
- the testing shall be performed in accordance with the provisions of E.4.2, E.4.3, E.4.4, E.4.6, E 4.8, and E.4.10 Annex E in order to determine the ultimate bond strength with the concrete.

F.5.3 While performing tests under Procedures A and B the pH value of the alkaline aqueous solution shall be measured before and after the tests.

F.5.4 External appearance of the specimen (color, variation of the surface and geometrical dimensions) should be examined before and after immersion into the alkaline aqueous solution in compliance with 8.1 and 8.8

F.5.5 When performing the strain capacity test the load shall be applied to the specimen at the rate of 5 to 15 mm/min.

F.5.6 When performing the pull-out test for bond strength the load shall be applied to the

specimen at the rate of not more than 20 N/min or 1 mm/min.

F.5.7 the material properties of bars shall be assessed only on the basis of the specimens undergoing failure in the test section. In the cases when tensile failure or slippage takes place at the testing sleeve, the data are disregarded and additional tests should be carried out with the specimens representing the same lot of production.

F.6 Processing of test results

F.6.1 Changing of the FRP bar mass Δm, % is calculated according to the formula:

$$\Delta m = \frac{m_1 - m_0}{m_0} 100 \qquad \text{(F.1)}$$

where m_1 is the mass of the specimen after immersion into the alkaline aqueous solution, g; m_0 is the mass of the specimen before immersion, g.

F.6 2 The ultimate strength limit is calculated according to the formula (B.1).

F 6.3 Variation of the ultimate strength limit $\Delta\sigma$, % is calculated according to the formula:

$$\Delta\sigma = \frac{\sigma_{в1} - \sigma_в}{\sigma_в} \qquad \text{(F.2)}$$

where σ_1 is the ultimate strength limit after immersion, MPa;

σ_2 is the ultimate strength limit before immersion, MPa.

F.6.4 The ultimate FRP bar-to-concrete bond strength is calculated according to the formula (E.3) Annex E.

F.6.5 Variation of the ultimate FRP bar -to-concrete bond strength $\Delta\tau_r$, % is calculated according to the formula:

$$\Delta\tau_r = \frac{\tau_{r1} - \tau_r}{\tau_r} \qquad \text{(F.3)}$$

where τ_{r1} is the ultimate FRP bar-to-concrete bond strength after immersion, MPa;

τ_r is the ultimate FRP bar-to-concrete bond strength before immersion, MPa.

Statistical processing of the test results shall be performed compliant to the requirements of GOST 8.207.

F.7 Test protocol

The test protocol shall include the following items:

- information about the specimens, as provided in the specimens sampling protocol;
- name of the testing facility that performed the testing;
- date of performance of testing;
- information about the conditions for performance of testing;
- geometrical characteristics of each specimen;
- information about the conditions for performance of testing (composition of the alkaline solution, the value of pH, temperature, and the immersion period and time);
- values of measured characteristics for each of the tested specimen (change of mass, the ultimate strength limit, and the module of elasticity);
- values of the characteristics determined for each of the specimens, which were obtained at processing of the results of the tests;
- average values of the determined characteristics and the results of statistical processing of the obtained results;
- type of load failure, curves of «load versus deformation» for each specimen;
- personal data of the experts engaged in performing the testing and their signatures.

Addendum G
(reference)

Maximum operating temperature test method

G.1 General provisions

This method establishes the procedure for determining the temperature of initial corrosion-resistant coating softening according to the results of the thermo mechanical tests.

G.2 Summary of test method

The method is based on thermo mechanical chart analysis obtained during the specimen test for cross three-point bending to a target value and the heat of the bent specimen in the heat chamber, registration of load changes as the temperature increases.

With the temperature growth, the flexural strength of the specimen is reducing. It happens due to the fact of resistance reduction of the polymer matrix composite by shearing stress, existing in the bent short specimen. Reduction speed of the specimen resistance to the bend has a maximum value in the period when the heated polymer matrix in the specimen begins to move from a glassy state to a flexible, that is softening.

During the subsequent differential thermal analysis obtained during the chart test describing the dependence of the specimen bending resistance on the temperature, the temperature at which the process of softening of the matrix has begun is determined.

G3 Specimens

G3.1 Specimens for testing are randomly selected from the controlled lot of corrosion-resistant coating and are always accompanied by the act of sampling, which indicates:

- manufacturer's name;
- conventional value;
- fiber and binder type;
- manufactured date;
- lot number;
- number and size of specimens;
- values for monitoring of which the specimens are selected;
- signature of the person responsible for the selection.

During the selection and preparation of the specimens for testing, straining and heating, effects of ultraviolet light and other environmental effects which may cause properties changes of the material should be avoided.

The number of specimens selected for testing, must comply with the requirements of Table 7.

G.3.2 The specimens length for testing should be 12d. The working area length of these specimens must be within 9d ± 2 mm.

G.3.3 The developmental prototypes before testing starts are kept in accordance with the requirements of GOST 12423.

G4 Equipment and materials

G.4.1 Testing machine as per GOST 28S40 should provide:

loading, exceeding the specimen durability during the testing for test item;

load and the distance measurement between the traverses with an error of no more than 0.5%;

conveying speed of the active traverse in the range of 5 to 100 m / min.

G.4.2 For specimens testing the device the scheme of which is shown in Figure G.1 must be applied.

G.4.3 The device consists of:

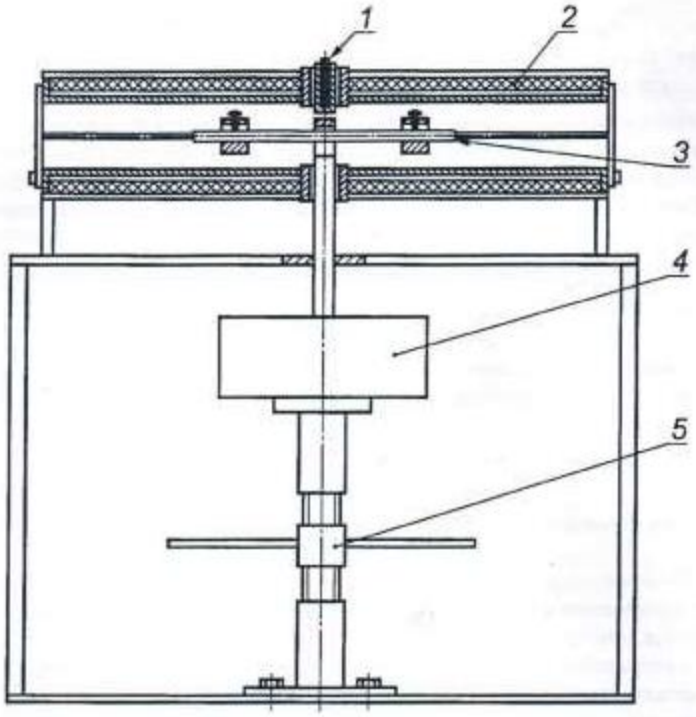
assembled on the frame of the heating chamber, which provides the possibility of heating the specimen to the temperature of 200 * C;

loading device;

force sensor with a measuring error not more than 0.5%;

temperature sensor with a measuring error not more than 1%;

The device must be equipped with a heating rate control means, which provide the temperature rise in the heating chamber in the range (1.0 ± 0,2) ° C / min and a measuring software complex for recording and processing the testing results.



1 – temperature measurement sensor; 2 – heating chamber; 3 – specimen; 4 – force measurement sensor;

5 – loading device

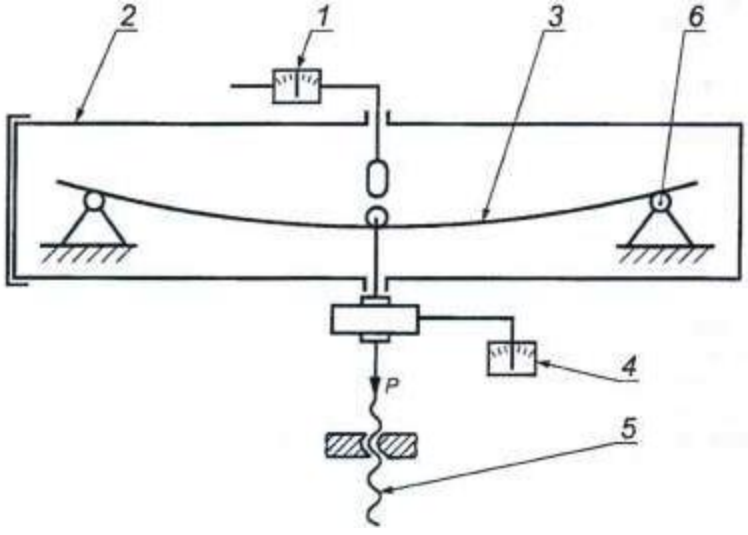
Figure G.1 - Device for thermo-mechanical tests

G.4.4 Testing scheme of the specimen while determining the temperature when the softening of the development prototype starts (see Figure G.2.);

the specimen 3 with the supports 8 are placed in the pre-cooled to room temperature heating chamber 2;

the specimen is bent by clamping the tip of the loading device 5 to a predetermined deflection value;

record the temperature in the heating chamber and the corresponding values of the specimen bending resistance force by sensors 6 and 7 during the test period;



1 — temperature measurement sensor: *2* — heating chamber: *3* — specimen; 4 — force measurement sensor;
5 — loading device; 6 — support

Figure G.2 — Testing scheme of the specimen while determining the temperature when the softening of the development prototype starts

- Turn on a heating chamber to the operating mode providing heating rate = 1 "C / min, and gradually heat to a predetermined temperature above the temperature in the second point of a-transition;
- during the chamber heating with a predetermined frequency the temperature value in the chamber and corresponding resistance value of the specimen to transverse bending are recorded.

G.5 Specimens testing

G.5.1 The test conditions shall comply with subsection 3.15 of GOST 15150.

G.5.2 The load acting on the specimen should be 10% of the value of the breaking load at a given test base (distance between supports). Expected value of the breaking load P, H is calculated using the formula:

$$P \approx \frac{4\sigma_в w}{l_p}, \quad \text{(G.1)}$$

where / p - the length of working area of the specimen, mm.

For a circular cross-section specimen the value w, mm3, is calculated with the formula

$$w = \frac{\pi d^3}{32}, \quad \text{(G.2)}$$

G.5.3 The testing device is set to a value of the test base, corresponding to the value / p.

G.5.4 Force and temperature measurement sensors are set.

G.5.5 The specimen is placed in the device, so that the pressure tip of the instrument influences the middle of the specimen working area, located between the supports.

G.5.6 With the help of loading device the specimen is bent until the load applied to it becomes equal to the load in accordance with G.5.2. The load is monitored by the indications of force measuring sensor.

G.5.7 The specimen is kept at a predetermined position for at least 5 minutes. After that the heating chamber is turned on to the operating mode and the temperature changes in it are monitored.

G.5.8 When the temperature in the chamber rises for 1 *C thermo mechanical c diagram – an array of temperature and force values T, P) is recorded.

G.5.9 The array is recorded with increment temperature changes not more than 2 * C.

G.5.10 After the test completion the specimen is removed from the chamber, the chamber is cooled to room temperature.

G.6 Processing of test results

G.6.1 While processing the test results the thermo mechanical charts of each tested specimen should be analyzed.

G.6.2 The chart of the specimen thermo mechanical diagram in the coordinates P(T), using the array (Tj, Pj), using experimental data processing program, for example «Microsoft Excel».

G.6.3 The approximate border position of the primary and the working areas of the diagram is visually estimated on the graph.

G.6.4 The initial section of the thermo mechanical curve (prior to the beginning of the softening of the polymer matrix) is approximated by a linear function Pj = m Tj + n and the constants m and n of this function are determined using the data processing program.

G.6.5 The reduced load Pj for each array value is determined with the formula

$$P_{1i} = \frac{P_i}{(mT_i + n)},$$

(G.3)

where Ti - temperature value in the array, , *C

Pi - force value in the array, H;

m and n – the values of the empirical constants of the straight line approximating initial section of the load depending Pi with which the specimen resists to bending from the temperature Ti, in the heating chamber.

G.6.6 The new data array (Ti, Pi) is built, the working area of which is approximated by the formula sigmoid

$$P_1 = a + \frac{b}{\left(1+\exp\left(-\frac{T-c}{d}\right)\right)},$$

(G.4)

where a. b, c, d - empirical constants of the sigmoid approximating the experimental data.

The function with number 8011of the software product «Table Curve Windows v 1.10» is recommended for determining constants.

G.6.7 The values of the first and second temperature derivative of the mathematical function [P (T)] is determined with the help of the software product «Table Curve Windows v. 110», by which the dependence working area of the given load values Pi applied to the specimen during the test, by temperature values Ti in a heating chamber is approximated.

G.6.8 The temperature value whereby the second derivative of the function [Pi (T)] has a minimum value is taken as the temperature Ti for which the numerical values of the function Pi, (T) and its first derivative CP / kT is found on the thermo mechanical diagrams.

G.6.9 The temperature value whereby the second derivative of the function [Pi (T)] has the maximum value is taken as the temperature Ti.

G.6.10 The temperature value whereby the first derivative of the function [Pi (T)] has the maximum value is taken as the temperature Tc, °C.

G.6.11 According to the obtained values of T0 and Tc G1ts the correctness of the preliminary borders assessment of the initial and the working area of the thermo mechanical curve diagram and decide on the need for re-treatment chart is evaluated and decide whether the repeated diagram processing is needed.

G.6.12 The limiting operating temperature T3."C is calculated with the formula

$$T_3 = T_{1\alpha} - \left(\frac{(1-P_{1\alpha})\cos(\theta)}{(1-\sin(\theta))}\right), \quad \text{(G.5)}$$

$$\theta = \frac{\pi}{2} + \operatorname{arctg}(\partial P_1/\partial T), \quad \text{(G.6)}$$

G.7 Test Accuracy

G.7.1 Temperature in the test chamber shall be measured with an error of not more than 2 “C.

G.7.2 Specimen resistance to cross bending shall be measured with an error of not more than 0.5% of the maximum value of the force obtained during testing.

G.7.3 The values that determine the characteristics, constants and other variables that are used in intermediate calculations should be determined with an accuracy of up to 0.001.

G.8 Test report

The test report shall include;

- Information about the specimens that are listed in the selection act of specimens;
- test date;
- information about the conditions under which the tests were done;
- tests results;

- the values of measured characteristics for each test specimen;
- the values of the determined characteristics of each specimen obtained while the processing the test results;
- average values of the determined characteristics and results of statistical processing of the received data;
- initial thermo mechanical test diagram of each specimen;
- the reduced thermo mechanical test diagram of each specimen;
- dependence diagram of the first derivative reduced load to the temperature for each specimen;
- dependence diagram of the second derivative reduced load to the temperature for each specimen;
- information about the test technicians, and their signatures.

Addendum H
(reference)

Passport form

PASSPORT №

Manufacturer:
(name, address, telephone, fax
)_____
Date of manufacture
_____
Shipping date
_____
Conventional value of corrosion-resistant coating
_____
Lot № _____
Lot weight, kg
_____
Total lot length _____ m
Number of products in the packaging _____ pieces
Regulated parameters of the quality

_____
____
The certificate availability (if certified)

Other regulated parameters of the quality (if necessary)

Issue date «__»_____20__year
Head of laboratory _____/_____/
(signature)
QC Department _____/_____/
(signature)
Bundler _____/
(signature)

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UDC 621.002.3: 006.354 ISS 91.080.40 H13 NEQ
Keywords: polymer composite reinforcement, acceptance rules, control methods, test methods

Editor O.I. Kashtanova
Technical editor V.N.Prusakova
Proofreader M.V. Buchnaya
Computer-aided makeup O.D. Cherepkovoy

Put for typing 24.12.2013. Signed for print 16.01.2014. Format 60x84 1/5 Arial headset.
Conv.print.sh. 4,65
published sheets 3,72. Edition 118 examples. Order 44.

Published and printed in FSUE «STANDARTINFORM», 4 Granatniy lane, Moscow, 123995
www.gostinfo.ru info@gostinfo.ru