

SOME ASPECTS OF TESTING FIBRE-REINFORCED POLYMER BARS UNDER SUSTAINED AND DYNAMIC LOADS AND VARIOUS EXPOSURES

*Evgeny Yu. Yurin*¹, *Sergey K. Khlebnikov*^{1,2}, *Ulyana V. Kudyakova*¹,
Konstantin L. Kudyakov^{1,2}, *Andrey V. Buchkin*¹

¹ Research Institute of Reinforced Concrete named after A.A. Gvozdev in JSC Research Center of Construction, Moscow, RUSSIA

² National Research Moscow State University of Civil Engineering, Moscow, RUSSIA

Abstract: The physical-mechanical and rheological properties of fibre-reinforced polymer bars (FRP bars) have been studied predominantly under short-term static loading. In real-world operation, reinforced concrete structures are subjected to a complex combination of various factors, including sustained loads, cyclic dynamic loads (including fully reversed), temperature effects, and exposure to aggressive environments. Russian regulatory documents for the design of reinforced concrete structures partially account for these factors using generalized reduction factors. Standard test methods for determining the combined influence of these factors on the properties of FRP bars are currently lacking.

The aim of this research is to identify a number of features in the preparation and implementation of tests to assess the combined influence of operational factors on the strength and deformation characteristics of FRP bars. The paper presents the prerequisites for developing a test program to study the behavior of reinforcement under long-term static loading under conditions of elevated temperature and alkaline environment of concrete, as well as under repeatedly applied dynamic load (including the fully reversed «compression-tension» mode) with varying cycle parameters. The goal is to derive analytical relationships and diagrams for the long-term strength and fatigue strength of FRP bars, which consider the influence of temperature, aggressive environment, and loading cycle parameters.

The obtained results form the basis for a comprehensive program of experimental research, the development of test methods, and the prediction of the behavior of FRP bars in real-world operating conditions as part of concrete structures. They enable a transition from using generalized coefficients to calculations that account for specific exposures. This is a key step towards improving the regulatory framework and designing reliable, durable, and safe reinforced concrete structures with FRP bars.

Keywords: fibre-reinforced polymer bars, strength, durability, sustained load, dynamic load, cyclic load, alkaline environment of concrete, temperature effect

НЕКОТОРЫЕ АСПЕКТЫ ИСПЫТАНИЙ АРМАТУРЫ КОМПОЗИТНОЙ ПОЛИМЕРНОЙ ПРИ ДЛИТЕЛЬНОЙ И ДИНАМИЧЕСКОЙ НАГРУЗКАХ И РАЗЛИЧНЫХ ВОЗДЕЙСТВИЯХ

*Е.Ю. Юрин*¹, *С.К. Хлебников*^{1,2}, *У.В. Кудякова*¹, *К.Л. Кудяков*^{1,2},
*А.В. Бучкин*¹

¹ Научно-исследовательский, проектно-конструкторский и технологический институт бетона и железобетона им. А.А. Гвоздева АО «Национальный исследовательский центр «Строительство», г. Москва, РОССИЯ

² Национальный исследовательский Московский государственный строительный университет, г. Москва, РОССИЯ

Аннотация: Физико-механические и реологические свойства арматуры композитной полимерной (АКП) изучены преимущественно в условиях кратковременного статического нагружения. В реальной эксплуатации железобетонные конструкции подвергаются комплексному воздействию различных факторов, в т.ч. длительные нагрузки, циклические динамические (включая знакопеременные) нагрузки,

температурные воздействия, воздействия агрессивных сред. Нормативные документы РФ по проектированию армированных бетонных конструкций частично учитывают данные факторы при помощи обобщенных коэффициентов. Стандартные методы испытаний по определению комплексного влияния данных факторов на свойства АКП в настоящее время отсутствуют.

Целью данного исследования является определение ряда особенностей при подготовке и реализации испытаний для оценки комплексного влияния эксплуатационных факторов на прочностные и деформационные характеристики АКП. В работе приведены предпосылки для составления программы испытаний по изучению поведения арматуры при длительном статическом нагружении в условиях повышенной температуры и щелочной среды, а также при многократно повторяющейся динамической нагрузке (включая знакопеременный режим «сжатие-растяжение») с варьируемыми параметрами цикла, с выявлением аналитических зависимостей и диаграмм длительной и усталостной прочности АКП, которые учитывают влияние температуры, агрессивной среды и параметров цикла нагружения.

Полученные результаты являются основой для выполнения комплекса экспериментальных исследований, разработки методов испытаний и прогнозирования поведения АКП в реальных условиях эксплуатации в составе бетонных конструкций и позволяют перейти от использования обобщенных коэффициентов к расчету с учетом конкретных воздействий. Это является ключевым шагом для совершенствования нормативной базы и проектирования надежных, долговечных и безопасных железобетонных конструкций с АКП.

Ключевые слова: арматура композитная полимерная, прочность, долговечность, длительная нагрузка, динамическая нагрузка, циклическая нагрузка, щелочная среда бетона, температурное воздействие

INTRODUCTION

The characteristics of fibre-reinforced polymer bars (FRP bars) have been primarily studied under short-term static loads [1, 2, 3, 4, 5]. Meanwhile, during the standard operation of reinforced concrete structures of buildings and facilities, other loads and exposures arise that must be considered in design, among which the following can be highlighted:

- sustained load (dead weight of structures and materials, the sustained part of live load, prestressing of reinforcement) [6, 7, 8, 9];
- short-term dynamic and repeatedly applied cyclic load with different cycle parameters (including fully reversed «compression-tension»), seismic action [5, 9, 10, 11, 12];
- temperature effects (including those approaching or exceeding the glass transition temperature of the polymers);
- exposure to the alkaline environment of concrete [3, 4, 6, 13];
- others.

Currently, in domestic and foreign codes for the design of reinforced concrete structures with FRP bars, the consideration of these loads and exposures (separately or in combination) is performed using generalized reduction factors or is not performed at all. However, in some

cases, these parameters can have a critical impact on the mechanical safety and reliability of such structures. For example, with poorly manufactured FRP bars, the combined action of elevated temperature and an alkaline environment can lead to degradation of the interphase layer, disrupting the bond between concrete and reinforcement. The manifestation of fatigue or creep in polymers under long-term dynamic or static loading, depending on the load parameters and material, can significantly reduce the strength of FRP bars. The resistance of FRP bars to compressive loads, which arise in the sections of compressed and eccentrically compressed reinforced concrete elements under long-term static and fully reversed dynamic loads, is currently not accounted for in the Russian codes and has been insufficiently studied [14].

MATERIALS AND METHODS

Along with leading research organizations, the Research Institute of Reinforced Concrete named after A.A. Gvozdev in JSC Research Center of Construction is engaged in comprehensive research in these areas, considering both individual factors and their combined influence.

A test program is being implemented to evaluate the strength of FRP bars under the separate and combined action of elevated temperature, alkaline environment, and sustained load with variation of their parameters.

Sustained load tests are performed on a special test stand with a vertical arrangement of specimens (Figure 1). A constant tensile load is applied to the specimens through a system of levers and calibrated weights, without restricting their strain. The load is monitored by a load cell. Testing is performed according to the methodology of GOST 32492-2024, considering the provisions of ASTM D7337/D7337M-12 (2019), ACI 440.3R-2012, CAN/CSA S806-12 (R2017), FIB Bulletin 40 [15, 16, 17, 18, 19]. In 2025, the automation of the test stand and its modernization for new types of tests are planned.



Figure 1. General view of long-term testing of FRP bar specimens (before test stand modernization)

The influence of an aggressive liquid environment is produced via additionally installed vessels in the form of tubes sealed at the

ends. Local controlled heating of the specimens is achieved using a heating cable.

Monitoring of longitudinal strain is performed automatically using high-precision LVDT sensors (prior to modernization, using mechanical strain gauges with dial indicators). The exact time and nature of failure are recorded using video recording.

A research program is also being implemented to study the strength and deformability of FRP bars under repeatedly applied dynamic load with various cycle parameters (including fully reversed loads and assessment of fatigue strength). The test methodology is based on the provisions of GOST 32492-2024 [15].

Tests are performed on specially prepared specimens (Figure 2) in automatic servohydraulic testing systems (Instron 8802, etc.), which allow applying an axial cyclic load with specified amplitude-frequency characteristics.

Measurement of longitudinal strain is carried out using high-frequency measurement systems connected to strain gauges, clip-on extensometers, and COD (Crack Opening Displacement) sensors.

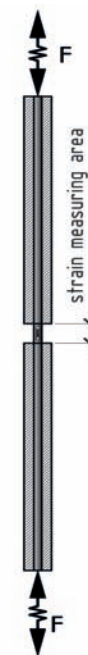


Figure 2. Schematic diagram of testing FRP bars under cyclic load with different values of the stress ratio (R)

It should be noted that this test scheme technically allows for the additional consideration of the influence of an aggressive environment and elevated temperatures, similar to the long-term tests.

It is also reasonable to investigate the possible influence of the specimen gauge length on the fatigue strength under axial fully reversed cyclic load according to the «compression-tension» mode.

RESULTS AND DISCUSSION

The described tests are aimed at obtaining analytical relationships and diagrams used for predicting the strength and strain of FRP bars in the design of reinforced concrete structures (Figures 3 and 4). These relationships and diagrams can be obtained based on GOST 32492-2024, taking into account the provisions of ASTM D7337/D7337M-12 (2019), ACI 440.3R-2012, CAN/CSA S806-12 (R2017) [15, 16, 17, 18].

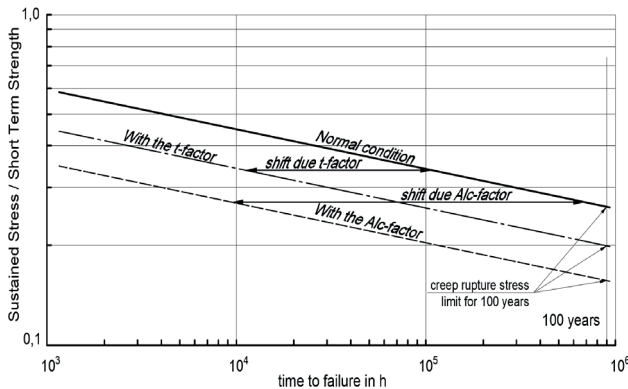


Figure 3. Characteristic predictive relationships and diagrams of the long-term strength of FRP bars under exposure to aggressive environments and elevated temperature

Figure 3 shows a characteristic predictive diagram of the long-term strength of FRP bars under normal operating conditions, as well as diagrams accounting for the influence of ambient temperature (t-factor) and exposure to aggressive environments (Alc-factor) under sustained tensile load (the diagrams are shown schematically and can be refined based on test results).

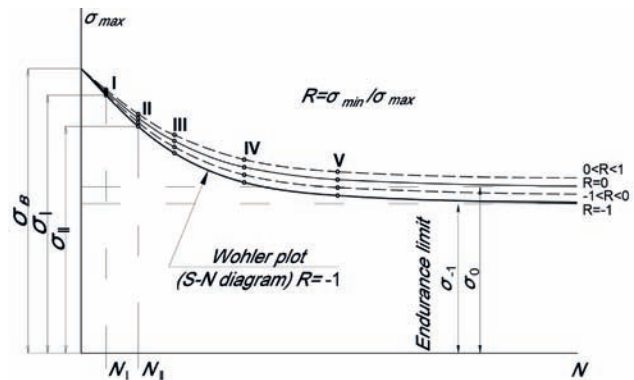


Figure 4. Characteristic predictive diagrams of the fatigue strength of FRP bars under cyclic repeatedly applied tensile load with different cycle asymmetry ratios (R)

Figure 4 shows characteristic predictive diagrams of the fatigue strength of FRP bars under cyclic repeatedly applied tensile load depending on the nature of the loading cycle. The Wohler plots (S-N diagrams) show the change in the strength of FRP bars (σ_i) after N_i loading cycles (the diagrams are shown schematically and can be refined based on test results).

The importance of validating the obtained results through additional studies of the stress-strain state of concrete structures reinforced with FRP bars under characteristic loadings and exposures should be noted.

CONCLUSION

1. The design of reliable and durable concrete structures reinforced with FRP bars requires accounting for multiple factors, including the influence of different types of loads and exposures on material characteristics. The insufficient number of studies is a barrier to the application of FRP bars.
2. The features of the tests on FRP bars under sustained and dynamic load, considering external exposures, being implemented at the Research Institute of Reinforced Concrete named after A.A. Gvozdev in JSC Research Center of Construction, are outlined.

3. Characteristic analytical graphs and relationships are proposed, which, considering the test results, can serve as a tool for designing concrete structures reinforced with FRP bars, accounting for the predicted degree of degradation of FRP bar properties under sustained loads and exposures.

4. The importance of validating the obtained results through additional studies of the stress-strain state of concrete structures reinforced with FRP bars under characteristic loadings and exposures should be emphasized.

ACKNOWLEDGEMENTS

The authors express their gratitude to Federal Autonomous Institution «Federal Center for Standardization» (FAU «FCC») and JSC Research Center of Construction for their support in conducting the research.

REFERENCES

1. **Plevkov V.S., Baldin I.V., Kudyakov K.L., Nevskii A.V.** Strength and deformability of polymer composites under tensile and compressive loads. *Journal of Construction and Architecture*. 2016; 5(58):91-101. (in Russian).
2. **Plevkov V.S., Tamrazyan A.G., Kudyakov K.L.** Strength and crack resistance of bent fiber-reinforced concrete elements with prestressed glass composite reinforcement under static and short-term dynamic loading. Tomsk, Publishing House of Tomsk State University of Architecture and Civil Engineering; 2021. (in Russian).
3. **Stepanova V.F., Stepanov A.Yu., Zhirkov E.P.** Composite polymer reinforcement. Moscow: ASV Publ.; 2013. (In Russian).
4. **Stepanova V.F., Buchkin A.V., Kudyakov K.L., Stepanov A.Yu.** Composite polymer fittings and composite polymer products. Moscow, 2023. (in Russian).
5. **Mamin A.N., Khlebnikov S.K.** Use Fiber-Reinforced Polymer Bars in Concrete Structures Subject to Dynamic Loads. *Reinforced Concrete Structures*. 2025; 1(9):26-34. (In Russian).
6. **Yurin E.Yu., Buchkin A.V., Kudyakov K.L.** Effects of alkaline concrete media on glass composite reinforcement under prolonged load action // Results of scientific and dissertation research : Collection of abstracts of the reporting scientific and technical session, Moscow, October 01-31, 2024. Moscow: Science and Research Center of Construction, 2024, pp. 20-21. (In Russian).
7. **Rossini M., Saqan E., Nanni A.** Prediction of the creep rupture strength of GFRP bars // *Construction and Building Materials*, 227, 116620(1-11), 2019. DOI : 10.1016/j.conbuildmat.2019.08.001.
8. **Benmokrane B., Brown V., Khaled M., Nanni A., Rossini M., Shield C.** Creep-Rupture Limit for GFRP Bars Subjected to Sustained Loads // *Journal of Composites for Construction*, 2019. 23. 06019001. 10.1061/(ASCE)CC.1943-5614.0000971.
9. **Tanks J., Naito K., Ueda H.** Characterization of the Static, Creep, and Fatigue Tensile Behavior of Basalt Fiber Polypropylene Composite Rods for Passive Concrete Reinforcement // *Polymers*, 13, 3136, 2021. <https://doi.org/10.3390/polym13183136>.
10. **Ray, B.C., Rathorea D.** A review on mechanical behavior of FRP composites at different loading speeds // *Critical reviews in solid state and materials sciences*. – 2015. – V. 40. – Pp. 119–135. DOI: 10.1080/10408436.2014.940443.
11. **Ochola R.O., Marcusa K., Nurick G.N., Franze T.** Mechanical behavior of glass and carbon fiber reinforced composites at varying strain rates // *Composite Structures*. – 2004. – V. 63. – Pp. 455–467.

12. **Tarek M.F.E.** Strength of prestressed bent beam elements reinforced with fiberglass reinforcement under the action of short-term dynamic loads [dissertation]. Moscow; 1992. (In Russian).
13. **Tu J., Hua X., Kui G.** Prediction of the Long-Term Performance and Durability of GFRP Bars under the Combined Effect of a Sustained Load and Severe Environments // *Materials*, 13, 2020. DOI: 10.3390/ma13102341.
14. **Kornev O., Kakusha V., Zhidkov Y., Lapshinov A., Mikhaldykin E.** Durability and structural evaluation of bridge girders prestressed with gfrp ties after 41 years of maintenance // 11th International Conference on Fiber-Reinforced Polymer (FRP) Composites in Civil Engineering (CICE 24-26 July 2023). <https://doi.org/10.5281/zenodo.8161100>.
15. GOST 32492-2024. Fibre-reinforced polymer bars for reinforcement of concrete structures. Methods for determining physical and mechanical characteristics, 2025 (In Russian).
16. ASTM D7337/D7337M-12. Standard Test Method for Tensile Creep Rupture of Fiber Reinforced Polymer Matrix Composite Bars, 2019.
17. ACI 440.3R. Guide Test Methods for Fiber-Reinforced Polymer (FRP) Composites for Reinforcing or Strengthening Concrete and Masonry Structures, 2012.
18. CAN/CSA S806-12 (R2017). Design and construction of building structures with fiber-reinforced polymers, 2017.
19. FIB Bulletin 40: FRP reinforcement in RC structures, 2007.
- статическом и кратковременном динамическом растяжении, и сжатии // Вестник ТГАСУ. 2016. №5 (58).
2. **Плевков, В.С.** Прочность и трещиностойкость изгибаемых фибробетонных элементов с преднапряженной стеклокомпозитной арматурой при статическом и кратковременном динамическом нагружении: монография / В.С. Плевков, А.Г. Тамразян, К.Л. Кудяков. –Томск: Изд-во Том. гос. архит.-строит. ун-та, 2021. – 204 с.
3. **Степанова, В.Ф.** Арматура композитная полимерная / В.Ф. Степанова, А.Ю. Степанов, Е.П. Жирков. – М. : АСВ, 2013. – 200 с.
4. **Степанова В.Ф., Бучкин А.В., Кудяков К.Л., Степанов А.Ю.** Арматура композитная полимерная и композитные полимерные изделия. Москва; 2023.
5. **Мамин А.Н., Хлебников С.К.** Использование композитной полимерной арматуры в бетонных конструкциях, подверженных динамическим воздействиям // Железобетонные конструкции. 2025. Т. 9. № 1. С. 26–34.
6. **Юрин Е.Ю., Бучкин А.В., Кудяков К.Л.** Влияние щелочных сред бетона на стеклокомпозитную арматуру при длительном действии нагрузки // Результаты научных и диссертационных исследований : Сборник тезисов докладов отчетной научно-технической сессии, Москва, 01–31 октября 2024 года. – Москва: Научно-исследовательский центр "Строительство", 2024. – С. 20-21.
7. **Rossini M., Saqan E., Nanni A.** Prediction of the creep rupture strength of GFRP bars // *Construction and Building Materials*, 227, 116620(1-11), 2019. DOI : 10.1016/j.conbuildmat.2019.08.001.
8. **Benmokrane B., Brown V., Khaled M., Nanni A., Rossini M., Shield C.** Creep-Rupture Limit for GFRP Bars Subjected to Sustained Loads // *Journal of Composites for*

СПИСОК ЛИТЕРАТУРЫ

1. **Плевков В.С., Балдин И.В., Кудяков К.Л., Невский А.В.** Прочность и деформативность арматуры композитной полимерной при
2. **Плевков, В.С.** Прочность и трещиностойкость изгибаемых фибробетонных элементов с преднапряженной стеклокомпозитной арматурой при статическом и кратковременном динамическом нагружении: монография / В.С. Плевков, А.Г. Тамразян, К.Л. Кудяков. –Томск: Изд-во Том. гос. архит.-строит. ун-та, 2021. – 204 с.
3. **Степанова, В.Ф.** Арматура композитная полимерная / В.Ф. Степанова, А.Ю. Степанов, Е.П. Жирков. – М. : АСВ, 2013. – 200 с.
4. **Степанова В.Ф., Бучкин А.В., Кудяков К.Л., Степанов А.Ю.** Арматура композитная полимерная и композитные полимерные изделия. Москва; 2023.
5. **Мамин А.Н., Хлебников С.К.** Использование композитной полимерной арматуры в бетонных конструкциях, подверженных динамическим воздействиям // Железобетонные конструкции. 2025. Т. 9. № 1. С. 26–34.
6. **Юрин Е.Ю., Бучкин А.В., Кудяков К.Л.** Влияние щелочных сред бетона на стеклокомпозитную арматуру при длительном действии нагрузки // Результаты научных и диссертационных исследований : Сборник тезисов докладов отчетной научно-технической сессии, Москва, 01–31 октября 2024 года. – Москва: Научно-исследовательский центр "Строительство", 2024. – С. 20-21.
7. **Rossini M., Saqan E., Nanni A.** Prediction of the creep rupture strength of GFRP bars // *Construction and Building Materials*, 227, 116620(1-11), 2019. DOI : 10.1016/j.conbuildmat.2019.08.001.
8. **Benmokrane B., Brown V., Khaled M., Nanni A., Rossini M., Shield C.** Creep-Rupture Limit for GFRP Bars Subjected to Sustained Loads // *Journal of Composites for*

- Construction, 2019. 23. 06019001. 10.1061/(ASCE)CC.1943-5614.0000971.
9. **Tanks J., Naito K., Ueda H.** Characterization of the Static, Creep, and Fatigue Tensile Behavior of Basalt Fiber Polypropylene Composite Rods for Passive Concrete Reinforcement // *Polymers*, 13, 3136, 2021. <https://doi.org/10.3390/polym13183136>.
 10. **Ray, B.C., Rathorea D.** A review on mechanical behavior of FRP composites at different loading speeds // *Critical reviews in solid state and materials sciences*. – 2015. – V. 40. – Pp. 119–135. DOI: 10.1080/10408436.2014.940443.
 11. **Ochola R.O., Marcusa K., Nurick G.N., Franz T.** Mechanical behavior of glass and carbon fiber reinforced composites at varying strain rates // *Composite Structures*. – 2004. – V. 63. – Pp. 455–467.
 12. **Тарек М.Ф.Э.** Прочность преднапряженных изгибаемых балочных элементов, армированных стеклопластиковой арматурой, при действии кратковременных динамических нагрузок [диссертация]. Москва; 1992.
 13. **Tu J., Hua X., Kui G.** Prediction of the Long-Term Performance and Durability of GFRP Bars under the Combined Effect of a Sustained Load and Severe Environments // *Materials*, 13, 2020. DOI: 10.3390/ma13102341.
 14. **Kornev O., Kakusha V., Zhidkov Y., Lapshinov A., Mikhaldykin E.** Durability and structural evaluation of bridge girders prestressed with gfrp ties after 41 years of maintenance // 11th International Conference on Fiber-Reinforced Polymer (FRP) Composites in Civil Engineering (CICE 24-26 July 2023). <https://doi.org/10.5281/zenodo.8161100>.
 15. ГОСТ 32492-2024 «Арматура композитная полимерная для армирования бетонных конструкций. Методы определения физико-механических характеристик», 2025.
 16. ASTM D7337/D7337M-12. Standard Test Method for Tensile Creep Rupture of Fiber Reinforced Polymer Matrix Composite Bars, 2019.
 17. ACI 440.3R. Guide Test Methods for Fiber-Reinforced Polymer (FRP) Composites for Reinforcing or Strengthening Concrete and Masonry Structures, 2012.
 18. CAN/CSA S806-12 (R2017). Design and construction of building structures with fiber-reinforced polymers, 2017.
 19. FIB Bulletin 40: FRP reinforcement in RC structures, 2007.

Evgeny Yurievich Yurin – Post graduate student, Senior Researcher, NIIZH named after A.A. Gvozdev, JSC Research Center of Construction, 6, bld. 5, 2nd Institutskaya str., Moscow, 109428, Russia, mx199107@bk.ru.

Sergey Konstantinovich Khlebnikov – Junior Researcher, NIIZH named after A.A. Gvozdev, JSC Research Center of Construction, 6, bld. 5, 2nd Institutskaya str., Moscow, 109428, Russia; Post graduate student, National Research Moscow State University of Civil Engineering, 26, Yaroslavskoe Shosse, Moscow, 129337, Russia, s.xlebnikov@mail.ru.

Евгений Юрьевич Юрин – аспирант, старший научный сотрудник, Научно-исследовательский, проектно-конструкторский и технологический институт бетона и железобетона (НИИЖБ) им. А.А. Гвоздева АО «НИЦ «Строительство», д. 6, корп. 5, 2-я Институтская ул., г. Москва, 109428, Россия, mx199107@bk.ru.

Сергей Константинович Хлебников – младший научный сотрудник, Научно-исследовательский, проектно-конструкторский и технологический институт бетона и железобетона (НИИЖБ) им. А.А. Гвоздева АО «НИЦ «Строительство», д. 6, корп. 5, 2-я Институтская ул., г. Москва, 109428, Россия; аспирант кафедры железобетонных и каменных конструкций. ФГБОУ ВО «Национальный исследовательский Московский государственный строительный университет» (НИУ МГСУ), д. 26, Ярославское шоссе, г. Москва, 129337, Россия, s.xlebnikov@mail.ru.

Ulyana Vladimirovna Kudyakova – Post graduate student, Structural Engineer, NIIZHВ named after A.A. Gvozdev, JSC Research Center of Construction, 6, bld. 5, 2nd Institutskaya str., Moscow, 109428, Russia, ulyana.pankratyeva@mail.ru.

Ульяна Владимировна Кудякова – аспирант, инженер-конструктор, Научно-исследовательский, проектно-конструкторский и технологический институт бетона и железобетона (НИИЖБ) им. А.А. Гвоздева АО «НИЦ «Строительство», д. 6, корп. 5, 2-я Институтская ул., г. Москва, 109428, Россия, ulyana.pankratyeva@mail.ru.

Konstantin Lvovich Kudyakov – Candidate in Technical Sciences, Head of Department, NIIZHВ named after A.A. Gvozdev, JSC Research Center of Construction, 6, bld. 5, 2nd Institutskaya str., Moscow, 109428, Russia; Associate Professor, National Research Moscow State University of Civil Engineering, 26, Yaroslavskoe Shosse, Moscow, 129337, Russia, konst_k@mail.ru.

Константин Львович Кудяков – кандидат технических наук, начальник отдела, Научно-исследовательский, проектно-конструкторский и технологический институт бетона и железобетона (НИИЖБ) им. А.А. Гвоздева АО «НИЦ «Строительство», д. 6, корп. 5, 2-я Институтская ул., г. Москва, 109428, Россия; доцент кафедры железобетонных и каменных конструкций. ФГБОУ ВО «Национальный исследовательский Московский государственный строительный университет» (НИУ МГСУ), д. 26, Ярославское шоссе, г. Москва, 129337, Россия, konst_k@mail.ru

Andrey Viktorovich Buchkin – Candidate of Technical Sciences, Deputy Director, NIIZHВ named after A.A. Gvozdev, JSC Research Center of Construction, 6, bld. 5, 2nd Institutskaya str., Moscow, 109428, Russia, andibuch@inbox.ru.

Андрей Викторович Бучкин – кандидат технических наук, заместитель директора, Научно-исследовательский, проектно-конструкторский и технологический институт бетона и железобетона (НИИЖБ) им. А.А. Гвоздева АО «НИЦ «Строительство», д. 6, корп. 5, 2-я Институтская ул., г. Москва, 109428, Россия, andibuch@inbox.ru.