DOI:10.22337/2587-9618-2025-21-2-129-137

EXPERIMENTAL DETERMINATION OF THE TOTAL SHRINKAGE STRAIN OF REINFORCED CONCRETE

Valeryia A. Rzhevutskaya, Yuliya G. Maskalkova
Belarusian-Russian University, Mogilev, BELARUS

Abstract: The article proposes a method for measuring the total shrinkage strain of a reinforced concrete prism in such a way that it is possible to measure the total shrinkage strain on an open surface of the prism no later than three hours after concreting. Furthermore, a monitoring of the strain increase on remaining surfaces of the prism after removing a formwork for concreting is followed. The object of this study is the shrinkage strain of expanded clay concrete and the strain of longitudinal reinforcement. Based on results of the conducted research, a new method for experimentally determining the total shrinkage strain of reinforced concrete was proposed. The suggested method makes it possible to ensure that the shrinkage strain of concrete begin to be recorded from the first day of concreting and the possibility of implementing the proposed method was experimentally confirmed. Prospects for further research are presented in the article.

Keywords: shrinkage, shrinkage strain, reinforced concrete, lightweight concrete, expanded clay concrete, expanded clay steel-reinforced concrete

ЭКСПЕРИМЕНТАЛЬНОЕ ОПРЕДЕЛЕНИЕ ПОЛНЫХ ДЕФОРМАЦИЙ УСАДКИ ЖЕЛЕЗОБЕТОНА

В.А. Ржевуцкая, Ю.Г. Москалькова
Белорусско-Российский университет, Могилев, БЕЛАРУСЬ

Аннотация: В статье предложен способ фиксирования полных деформаций усадки железобетонной призмы таким образом, чтобы было обеспечено измерение полных деформаций усадки на открытой грани не позднее, чем через три часа после бетонирования, с последующим контролем прироста деформаций по остальным граням призмы после ее распалубки. Объектом настоящего исследования являются усадочные деформации керамзитобетона и деформации продольной арматуры. По результатам проведенных исследований предложен новый способ экспериментального определения полных деформаций усадки железобетона, позволяющий обеспечить начало фиксирования деформаций усадки бетона, начиная с первых суток, и экспериментально подтверждена возможность реализации предложенного способа. Представлены перспективы дальнейших исследований.

Ключевые слова: усадка, деформации усадки, железобетон, легкий бетон, керамзитобетон, керамзитожелезобетон

INTRODUCTION

The complex hardening process of cement stone, the structure of concrete, capillary phenomena, and many other related factors causes the development of concrete shrinkage [1–4].

The shrinkage strain of concrete reinforced with bar reinforcement are lower than the strain of unreinforced concrete with the same components of concrete mixture, as noted in the studies [5, 6]. This is due to the fact that the reinforcement acts as an internal connection in the composite and ‘restrains’ the development of unrestrained shrinkage strain of the concrete since the elastic modulus of the reinforcement is significantly higher than the elastic modulus of concrete. As a result of a long shrinkage process, tensile forces arise in the cement stone, and compressive forces arise in the reinforcing bars. Consequently, the reinforcing bars become a source of additional stresses in the concrete [1].

According to GOST 24544-81, the measurements of concrete shrinkage strain are carried out the next day after concreting, then on the 3rd, 7th, 14th day, and then once every 2 weeks until the end of the investigation. However, it is well known that shrinkage strain develops most intensively in the first day of concrete hardening [7–10]; therefore, using the method based on GOST 24544, a significant part of concrete shrinkage strain will not be recorded. A review of many works, published by researchers from different countries, revealed a lack of proposals for the experimental strain determination in reinforcement bars caused by shrinkage.

Thus, it seems promising to develop such a method for experimentally determining the total shrinkage strain of reinforced concrete, which will make it possible to begin recording concrete shrinkage strain and reinforcement strain (caused by concrete shrinkage) from the first day of concrete hardening.

In the future, the presence of such a method will allow, on the one hand, to verify design models applicable for concrete with cement CEM Class N and, on the other hand, to use the proposed method for an empirically based assessment of the influence of other types of reinforcement (for instance, dispersed) on shrinkage strain development.

Based on the above, the object of the study is the shrinkage strain of expanded clay concrete and the strain of longitudinal reinforcement. The subject of the study is an expanded clay-reinforced concrete sample in the form of a prism with dimensions of 150 × 150 × 600 mm.

The purpose of this study is to implement such a method for measuring the total shrinkage strain of a reinforced concrete prism, which will make it possible to measure the total shrinkage strain on an open surface no later than three hours after concreting. In addition, a subsequent monitoring of the increase in strain along remaining surfaces of the prism after it's removing out of a formwork for concreting should be proposed.

METHODS

The following composition of the expanded clay concrete mixture was chosen for the manufacture of specimens according to [11, 12]: $C : S : G = 1 : 1{,}84 : 0{,}79$ and $W/C = 0.52$. Thus, C is Portland cement with activity of 42.5 MPa produced by Belarusian Cement Plant OJSC. S is river sand with a bulk density of 1670 kg/m^3 and fineness modulus of 2.13. G is expanded clay gravel with particle size of 4–10 mm and compressive cylinder strength of 1.03 MPa produced by Plant of expanded clay gravel in Novolukoml OJSC. W/C is water-cement ratio.

The shrinkage strain of the expanded clay steel-reinforced concrete was recorded on experimental samples (prisms) with dimensions of 150 × 150 × 600 mm. The duration of testing of each specimen was 120 days. During this time, normal temperature and humidity conditions had been maintained in the laboratory in accordance with GOST 24544-81: an average relative air humidity was 55 % and an average temperature was 22 ºC.

The measurement of the total shrinkage strain of the expanded clay steel-reinforced concrete (the samples in shape of prisms) was carried out in the following sequence.

1. Spatial reinforcement cages consisting of longitudinal and transverse reinforcement were manufactured [13].

Reinforcing bars with a diameter of 16 mm with the yield strength of 500 MPa (the longitudinal reinforcement; the percentage of the longitudinal bar reinforcement was $\rho_s = 3.57$ %) and with a diameter of 6 mm with the yield strength of 240 MPa (the transverse reinforcement) were used for manufacture of the reinforcement cages (Figure 1).

Figure 1. Spatial reinforcement cage for manufacture of specimens

2. Perforating holes were made at the ends on both sides in each longitudinal reinforcement bar, and through the holes steel adapter fittings were installed (Figure 2).

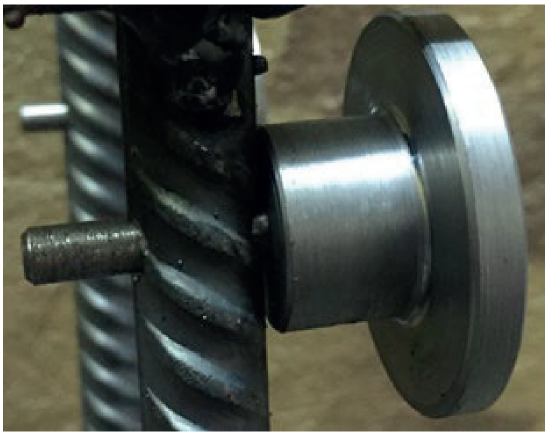

Figure 2. Steel adapter fitting in the longitudinal reinforcement bar

3. The reinforcement cage with the installed steel adapter fittings in it was inserted into a concreting formwork in such a way that the steel adapter fittings were flush with the concreting formwork along the entire surface area of the base of the steel adapter fittings (Figure 3).

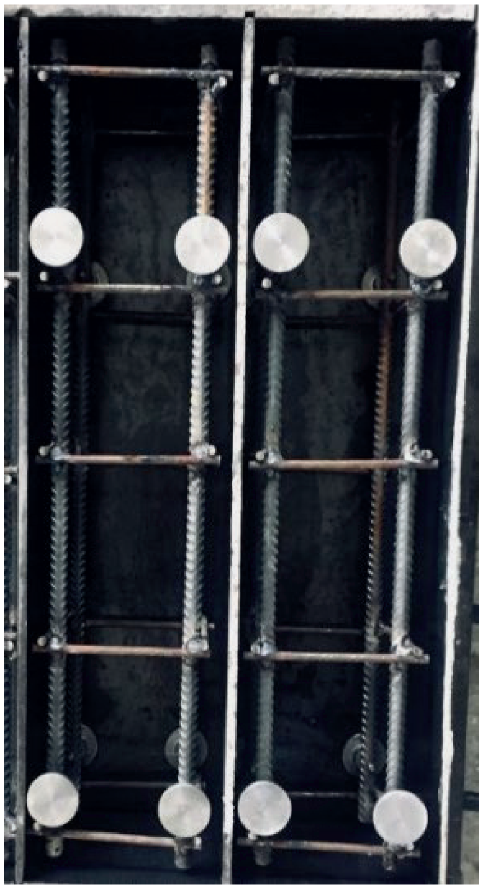

Figure 3. Reinforcement cage inserted in concreting formwork

4. The specimens were concreted in such a way that on the open surface of the horizontally oriented prism the base of the steel adapter fitting was flush with the surface of the laid concrete.
5. The bases of the steel adapter fittings on the open surface of the prism were cleared of concrete sagging and cement laitance after concreting.
6. Steel adapter points were attached to the bases of the steel adapter fittings on the open surface of the prism forty-five minutes after concreting. The steel adapter points were also immersed into the concrete mixture between the steel adapter fittings to a depth not less than the maximum aggregate size.

7. Two hours after installing the steel adapter points, they were connected in pairs to each other by steel rods, which were the base for measuring.
8. Dial-type indicators were installed into the steel adapter points. Thus, the strain in the longitudinal reinforcement bars and in the concrete between the longitudinal reinforcement bars were recorded.
9. The steel rods and the dial-type indicators were installed in a designed position with screws.
10. After removing the experimental prisms out of the formwork, steel adapter points were attached to the bases of the steel adapter fittings on an opposite surface of the prism to record strains in the reinforcement bars. The steel adapter points were also attached to the concrete surface on three surfaces of the prism except for the open surface during the concreting process. The steel adapter points were connected in pairs with steel rods, and then indicators were installed. The steel rods and the dial-type indicators were installed in a designed position with screws (Figure 4).

Figure 4. Dial-type indicators installed into steel adapter points to record shrinkage strain of expanded clay concrete and stain of longitudinal reinforcement

RESULTS AND DISCUSSION

During the investigation, three Series of twin specimens were sequentially tested (three twin samples in each Series). As a result of the research, experimental data had been obtained on the development of the total shrinkage strain of the expanded clay steel-reinforced concrete during 120 days. The experimental data are presented in Table 1 and Figure 5.

Table 1. Mean values of relative strain of the total shrinkage of experimental expanded clay steel-reinforced concrete specimens in form of prisms

Measured parameter in experimental specimens	Series No.	Mean values of relative strain of the total shrinkage						
		1st day	7th day	10th day	28th day	62nd day	91st day	120th day
Strain of expanded clay concrete $\varepsilon_{lcs,s} \times 10^5$	2	-0.61	0.38	0.95	9.27	10.08	12.85	13.85
	3	-0.40	0.36	0.93	9.28	10.51	13.11	14.33
	4	-0.41	0.38	0.94	9.14	11.19	13.41	14.61
Strain of longitudinal reinforcement $\varepsilon_{ss} \times 10^5$	2	0.02	0.48	2.29	5.69	12.78	15.03	15.93
	3	0.03	0.46	2.05	5.73	12.73	15.33	15.98
	4	0.03	0.48	2.27	6.39	12.52	15.01	15.90

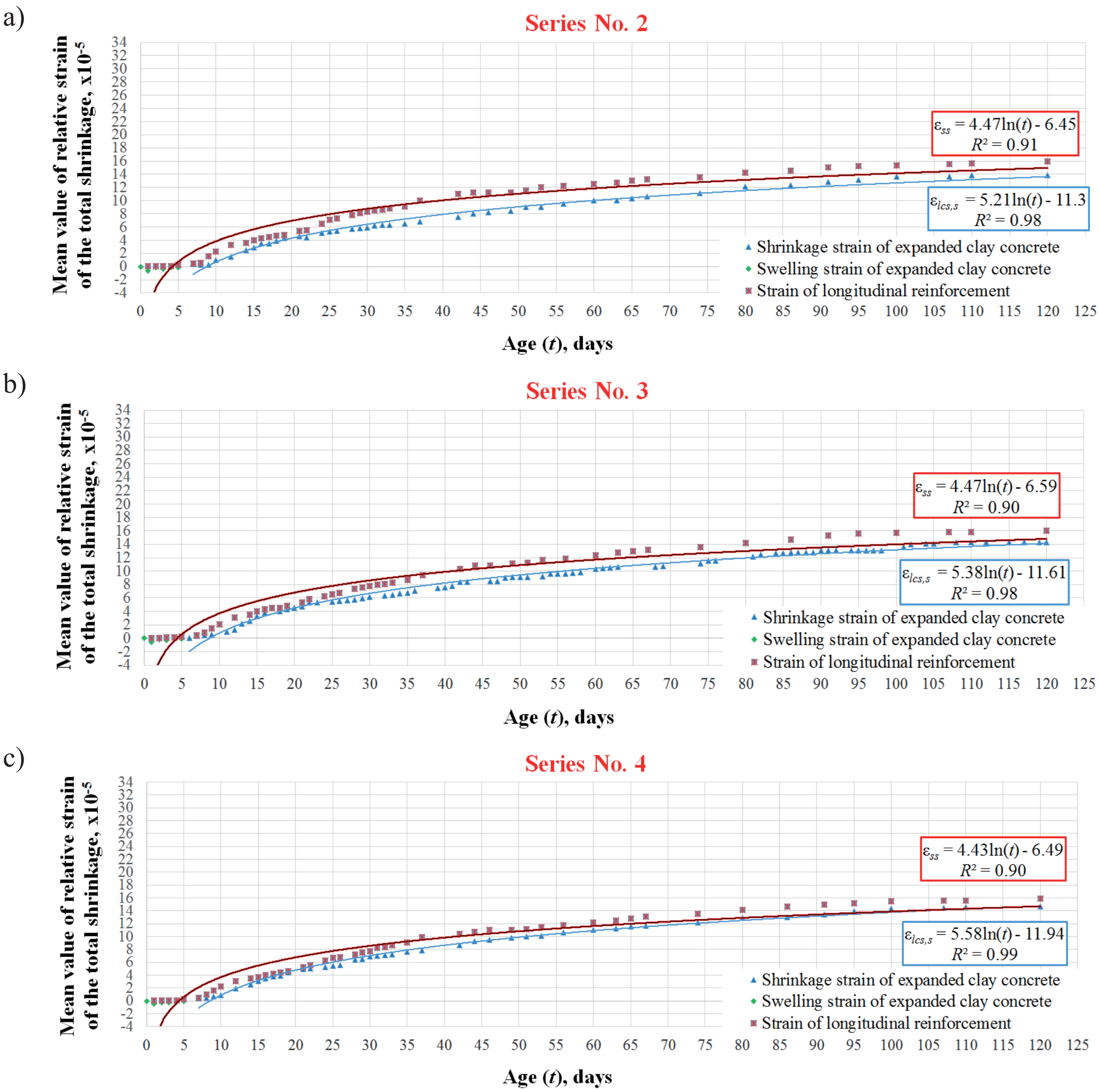

Figure 5. Development of relative strain of the total shrinkage of expanded clay steel-reinforced concrete (a – Series No. 2, b – Series No. 3, c – Series No. 4)

The results of the empirical study, as shown in Figure 5 and Table 1, confirm that the proposed implementation of the method provides measurements of the concrete shrinkage strain between longitudinal reinforcement bars and the strain of longitudinal reinforcement bars, starting from the first day of concreting.

In addition, some researchers [14–20] note a decrease in shrinkage deformation as a result of the addition of fibers to the expanded clay mixture. Nevertheless, the authors do not focus on a factor that affects an absolute value of the total shrinkage strain of fiber-reinforced concrete.

The application of the proposed method made it possible to prove experimentally that low-modulus polypropylene fibers act as an internal bond at an early hardening stage. As a result, there is a stress redistribution in the 'hydrated cement – polypropylene fiber' system, thereby it makes a significant effect on reducing the shrinkage stresses inside the composite [21].

CONCLUSIONS

Based on the results of the study, the new method has been proposed for experimentally measuring the total shrinkage strain of reinforced concrete. The method makes possible to ensure that shrinkage strain begin to be observed starting from the first day of concreting.

This implementation of the method for shrinkage strain measuring of expanded clay steel-reinforced concrete allows recording the total shrinkage strain of an experimental prism on an open surface no later than three hours after concreting, followed by monitoring an increase in strain along remaining surfaces of the prism (after it's removing out of a formwork for concreting).

REFERENCES

1. **Lazouski D.N., Tur V.V., Gluhov D.O., Lazouski Y.D.** (2021) Uchet polzuchesti i usadki betona po SP 5.03.01-2020 pri raschete zhelezobetonnyh konstrukcij na osnove deformacionnoj raschetnoj modeli [Creep and shrinking of concrete accounting according to SP 5.03.01-2020 when analysis of reinforced concrete structures based on deformational analytical model]. *Vestnik Brestskogo gosudarstvennogo tekhnicheskogo universiteta* [*Vestnik of the Brest State Technical University*], vol. 2(125), pp. 7–12. doi:10.36773/1818-1212-2021-125-2-7-12. (In Russian)
2. **Bazant Z.P.** (2001) Prediction of concrete creep and shrinkage: past, present and future. *Nu clear Engineering and Design*, vol. 203, iss. 1, pp. 27–38. doi:10.1016/S0029-5493(00)00299-5.
3. **Rzhevutskaya V.A.** (2020) Shrinkage of expanded clay concrete: A review. *AlfaBuild*, vol. 15, iss. 3, 6 p. doi:10.34910/ALF.15.1.
4. **Krivitskiy P., Shelest H., Nevdakh A., Sedlyr T.** (2024) Fiziko-mekhanicheskie harakteristiki konstrukcionnogo keramzitobetona v praktike sovremennogo stroitel'stve [Physical and mechanical characteristics of structural expanded direction concrete in the practice of modern construction]. *Vesnik Hrodzenskaha Dziarzhaunaha Universiteta Imia Ianki Kupaly. Seryia 6. Tekhnika* [*Bulletin of the Yanka Kupala Grodno State University. Series 6, Engineering*], vol. 14, iss. 2, pp. 33–35. Available at: https://vesnik.grsu.by/?p=s6&lang=ru. (In Russian)
5. **Bondarenko V.M., Suvorkin D.G.** (1987) Reinforced concrete and stone structures. *Vysshaya shkola* [*Higher education*], 386 p. (In Russ.). Available at: https://gbk.kgasu.ru/images/stories/metodmat/BondarenkoSuvorkinGbiKamKonstr_1987.pdf.
6. **Babich E.M.** (1988) Konstrukcii iz legkih betonov na poristyh zapolnitelyah [Structures made of light concrete on porous aggregates]. *Vysshaya shkola* [*Higher education*], 207 p. Available at: https://knizhen-pazar.net/products/books/746359-konstruktsii-iz-legkih-betonov-na-porist-h-zapolnitelyah. (In Russian)
7. **Bentur A., Igarashi Sh., Kovler K.** (2001) Prevention of autogenous shrinkage in high-strength concrete by internal curing using wet lightweight aggregates. *Cement and Concrete Research*, vol. 31, pp. 1587–1591. Available at: doi:10.1016/S0008-8846(01)00608-1.
8. **Zhuang Y., Zheng D., Zhen Ng., Ji T., Chen X.** (2016) Effect of lightweight aggregate type on early-age autogenous shrinkage of concrete. *Construction and*

Building Materials, vol. 120, pp. 373–381. doi:10.1016/j.conbuildmat.2016.05.105.

9. **Clarke J.L.** (2005) *Structural lightweight aggregate concrete*. Glasgow: Blackie Academic & Professional, an imprint of Chapman & Hall, 161 p.
10. **Wendling A., Sadhasivam K., Floyd R.W.** (2018) Creep and shrinkage of lightweight self-consolidating concrete for prestressed members. *Construction Building Materials*, vol. 167, pp. 205–215. doi:10.1016/j.conbuildmat.2018.02.017.
11. **Maskalkova Y.G., Rzhevutskaya V.A.** (2022) Compressive cylinder strength and deformability of expanded clay fiber-reinforced concrete with polypropylene fiber. *International Journal for Computational Civil and Structural Engineering*, vol. 18, iss. 2, pp. 31–42. doi:10.22337/2587-9618-2022-18-2-31-42.
12. **Maskalkova Yu.G., Rzhevutskaya V.A.** (2022) Size effect of cube specimen on strength of expanded clay fiber-reinforced concrete. *Magazine of Civil Engineering*, vol. 116, iss. 8, 18 p. doi:10.34910/MCE.116.12.
13. **Semenyuk S., Maskalkova Yu., Rzhevutskaya V.** (2020) Osobennosti opredeleniya stesnennoj usadki keramzitozhelezobetona [Features of determining restricted shrinkage of reinforced claydite-concrete]. *Vestnik Polockogo gosudarstvennogo universiteta* [*Vestnik of the Polotsk State University*], vol. 8, pp. 58–65. Available at: https://elib.psu.by/handle/123456789/25843. (In Russian)
14. **Kuryatnikov Yu.Yu., Kochetkov R.S.** Razrabotka matematicheskih modelej fiziko-mekhanicheskih svojstv modificirovannogo keramzitobetona [Development of mathematical models of physico-mechanical properties of modified expanded clay concrete]. *Innovacii i modelirovanie v stroitel'nom materialovedenii* [*Innovations and modeling in building materials science*], pp. 64–69. Available at: https://elib.tstu.tver.ru/MegaPro/Download/MObject/30794/001-000135274-000000000-0000-0000-01.pdf. (In Russian)
15. **Suvorov I.O.** (2016) Dispersnoe poliarmirovanie kak sposob snizheniya usadki fibropenobetona [Dispersed polyarming as a way to reduce shrinkage of fibropenocrete]. (PhD Thesis). S.-Petersburg: St. Petersburg State University of Architecture and Civil Engineering, 137 p. Available at: https://www.dissercat.com/content/dispersnoe-poliarmirovanie-kak-sposob-snizheniya-usadki-fibropenobetona/read. (In Russian)
16. **Costa H., Júlio E., Lourenço J.** (2012) New approach for shrinkage prediction of high-strength lightweight aggregate concrete. *Constructions and Buildings materials*, vol. 35, pp. 84–91. doi:10.1016/j.conbuildmat.2012.02.052.
17. **Zhao H., Ma Y., Zhang J., Hu Zh., Li H., Wang Y., Liu J., Wang K.** (2022) Effect of clay content on shrinkage of cementitious materials. *Construction and Building Materials*, vol. 157, 12 p. doi:10.1016/j.conbuildmat.2021.125959.
18. **Zhao S., Li Ch., Zhao M., Zhang X.** (2016) Experimental study on autogenous and drying shrinkage of steel fiber reinforced lightweight-aggregate concrete. Advances in Materials Science and Engineering, vol. 2016, 9 p. doi:10.1155/2016/2589383.
19. **Gong J, Zeng W., Zhang W.** (2018) Influence of shrinkage-reducing agent and polypropylene fiber on shrinkage of ceramsite concrete. *Construction and Building Materials*, vol. 159, pp. 155–163. doi:10.1016/j.conbuildmat.2017.10.064.
20. **Hussein Z.M., Khalil W.I., Ahmed H.K.** (2020) Shrinkage and impact strength of fibre-reinforced artificial lightweight aggregate concrete. Materials Science and Engineering, vol. 671, iss. 1, pp. 1–11. doi:10.1088/1757-899X/671/1/012118.

21. **Rzhevutskaya V.A., Moskal'kova Yu.G.** (2024) Polypropylene fiber as a factor of reduction the total shrinkage strain of expanded clay concrete. *Russian Journal of Building Construction and Architecture*, vol. 64, pp. 6–15. doi:10.36622/2542-0526.2024.64.4.001.

СПИСОК ЛИТЕРАТУРЫ

1. **Лазовский Д.Н., Тур В.В., Глухов Д.О., Лазовский Е.Д.** Учет ползучести и усадки бетона по СП 5.03.01-2020 при расчете железобетонных конструкций на основе деформационной расчетной модели // Вестник Брестского государственного технического университета, 2021, № 2 (125). С. 7–12. doi:10.36773/1818-1212-2021-125-2-7-12.
2. **Bazant Z.P.** Prediction of concrete creep and shrinkage: past, present and future // Nuclear Engineering and Design, 2001, No. 203, pp. 27–38. doi:10.1016/S0029-5493(00)00299-5.
3. **Rzhevutskaya V.A.** Shrinkage of expanded clay concrete: A review // AlfaBuild, 2020, No. 15(3), 6 p. doi:10.34910/ALF.15.1.
4. **Кривицкий П.В., Шелест Е.В., Невдах А.А., Седляр Т.Н.** Физико-механические характеристики конструкционного керамзитобетона в практике современного строительстве // Вестник Гродненского государственного университета имени Янки Купалы. Серия 6, Техника, 2024, Том 14, № 1. С. 35-43. Режим доступа: https://vesnik.grsu.by/?p=s6&lang=ru.
5. **Бондаренко В.М., Суворкин Д.Г.** Железобетонные и каменные конструкции // Высшая школа, 1987. 386 с. Режим доступа: https://gbk.kgasu.ru/images/stories/metodmat/BondarenkoSuvorkinGbiKamKonstr_1987.pdf.
6. **Бабич Е.М.** Конструкции из легких бетонов на пористых заполнителях // Киев : Вища Школа, 1988. 207 с. Режим доступа: https://knizhen-pazar.net/products/books/746359-konstruktsii-iz-legkih-betonov-na-porist-h-zapolnitelyah.
7. **Bentur A., Igarashi Sh., Kovler K.** Prevention of autogenous shrinkage in high-strength concrete by internal curing using wet lightweight aggregates // Cement and Concrete Research. 2001б No. 31, pp. 1587–1591. doi:10.1016/S0008-8846(01)00608-1.
8. **Zhuang Y., Zheng D., Zhen Ng., Ji T., Chen X.** Effect of lightweight aggregate type on early-age autogenous shrinkage of concrete // Construction and Building Materials, 2016, No. 120, pp. 373–381. doi:10.1016/j.conbuildmat.2016.05.105.
9. **Clarke J.L.** Structural lightweight aggregate concrete. Glasgow: Blackie Academic & Professional, an imprint of Chapman & Hall, 2005, 161 pages.
10. **Wendling A., Sadhasivam K., Floyd R.W.** Creep and shrinkage of lightweight self-consolidating concrete for prestressed members // Construction Building Materials, 2018, No. 167, pp. 205–215. doi:10.1016/j.conbuildmat.2018.02.017.
11. **Maskalkova Y.G., Rzhevutskaya V.A.** Compressive cylinder strength and deformability of expanded clay fiber-reinforced concrete with polypropylene fiber // International Journal for Computational Civil and Structural Engineering, 2022, No. 18, pp. 31–42. doi:10.22337/2587-9618-2022-18-2-31-42.
12. **Maskalkova Yu.G., Rzhevutskaya V.A.** Size effect of cube specimen on strength of expanded clay fiber-reinforced concrete // Magazine of Civil Engineering, 2022, No. 116(8), 18 pages. doi:10.34910/MCE.116.12.
13. **Семенюк С.Д., Москалькова Ю.Г., Ржевуцкая В.А.** Особенности определения стесненной усадки керамзитожелезобетона // Вестник Полоцкого гос. ун-та. Серия F.

Строительство. Прикладные науки. Новополоцк, 2020, № 8. С. 58–65. Режим доступа: https://elib.psu.by/handle/123456789/25843.
14. **Курятников Ю.Ю., Кочетков Р.С.** Разработка математических моделей физико-механических свойств модифицированного керамзитобетона // Инновации и моделирование в строительном материаловедении, 2019. С. 64–69. Режим доступа: https://elib.tstu.tver.ru/MegaPro/Download/MObject/30794/001-000135274-000000000-0000-0000-01.pdf.
15. **Суворов И.О.** Дисперсное полиармирование как способ снижения усадки фибропенобетона : дис. … канд. техн. наук : 05.23.05. Санкт-Петербург, 2015. 137 с. Режим доступа: https://www.dissercat.com/content/dispersnoe-poliarmirovanie-kak-sposob-snizheniya-usadki-fibropenobetona/read.
16. **Costa H., Júlio E., Lourenço J.** New approach for shrinkage prediction of high-strength lightweight aggregate concrete // Constructions and Buildings materials, 2012, No. 35, pp. 84–91. doi:10.1016/j.conbuildmat.2012.02.052.
17. **Zhao H., Ma Y., Zhang J., Hu Zh., Li H., Wang Y., Liu J., Wang K.** Effect of clay content on shrinkage of cementitious materials // Construction and Building Materials, 2022, No. 157, 12 pages. doi:10.1016/j.conbuildmat.2021.125959.
18. **Zhao S., Li Ch., Zhao M., Zhang X.** Experimental study on autogenous and drying shrinkage of steel fiber reinforced lightweight-aggregate concrete // Advances in Materials Science and Engineering, 2016, No. 2016. 9 pages. doi:10.1155/2016/2589383.
19. **Gong J, Zeng W., Zhang W.** Influence of shrinkage-reducing agent and polypropylene fiber on shrinkage of ceramsite concrete. Construction and Building Materials, 2018, No. 159, pp. 155–163. doi:10.1016/j.conbuildmat.2017.10.064.
20. **Hussein Z.M., Khalil W.I., Ahmed H.K.** Shrinkage and impact strength of fibre-reinforced artificial lightweight aggregate concrete // Materials Science and Engineering, 2020, No. 671(1), pp. 1–11. doi:10.1088/1757-899X/671/1/012118.
21. **Rzhevutskaya V.A., Moskal'kova Yu.G.** Polypropylene fiber as a factor of reduction the total shrinkage strain of expanded clay concrete // Russian Journal of Building Construction and Architecture, 2024, No. 64, pp. 6–15. doi:10.36622/2542-0526.2024.64.4.001.

Yuliya G. Maskalkova. PhD. in Engineering, Associate Professor, Associate Professor at the Department of Industrial and Civil Construction, Belarusian-Russian University, Mira Ave, 43, Mogilev, 212000, Belarus, e-mail: julia43@tut.by; ORCID ID: 0000-0002-4107-2452

Valeryia A. Rzhevutskaya. Senior lecturer at the Department of Industrial and Civil Construction, Belarusian-Russian University, Mira Ave, 43, Mogilev, 212000, Belarus, e-mail: valeriarzhevuckaya@gmail.com; ORCID ID: 0000-0001-8854-5408

Москалькова Ю. Г. К.т.н, доцент, доцент кафедры «Промышленное и гражданское строительство», Белорусско-Российский университет, пр. Мира, 43, Могилев, 212000, Беларусь, e-mail: julia43@tut.by; ORCID ID: 0000-0002-4107-2452

Ржевуцкая В. А. Ст. преподаватель кафедры «Промышленное и гражданское строительство», Белорусско-Российский университет, пр. Мира, 43, Могилев, 212000, Беларусь, e-mail: valeriarzhevuckaya@gmail.com; ORCID ID: 0000-0001-8854-5408