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Concrete Heat Treatment Methods

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Abstract. The article presents the results of studies of the influence of ambient temperature on the modes of heat and moisture treatment of concrete. The method of assignment of modes of heat and moisture treatment of concrete, taking into account the temperature of the hot climate, is proposed.

Keywords: Energy Efficiency, Concrete, Climate, Temperature, Industry, Reinforced Concrete, Technology.

I. Introduction

The Republic of Uzbekistan has adopted a number of key decrees aimed at increasing energy efficiency in the economic and social sectors, introducing energy efficient and energy saving technologies, further developing renewable energy, and ensuring the rational use of energy resources.

The precast concrete industry is one of the largest energy consumers among other sectors of the national economy. At present, heat treatment is an integral and at the same time the longest process in the production of precast concrete.

Despite some success, heat and moisture treatment has been and remains the longest technological redistribution of precast concrete production, taking 80-90% of the total time required for the manufacture of products.

Currently, over 90% of factory production is subjected to steaming, and more than half of the total volume is produced according to the aggregate flow technology with heat treatment in pit steaming chambers.

The main advantage of steam heating is the ability to provide favorable moisture conditions for concrete hardening, when the steam is in direct contact with the unformulated surface of the products. The widespread use of steam heating in the production of prefabricated reinforced concrete in our country and abroad is explained not so much by the advantages of the method as by its thorough study and great practical experience.

To accelerate the hardening of concrete in prefabricated structures, steam heat treatment has been used since the beginning of the last century.

Numerous studies have been and are being carried out on this issue, and the method is well described in a number of works by S.A. Mironov, L.A. Malinina and B.A. Krylov [1,2].

Depending on the adopted manufacturing technology, the conditions for heat treatment of products change: the concrete is heated either through the metal of the mold, or through direct contact of the product with the coolant. In this regard, the question arose about the processing of optimal steaming modes in relation to specific production conditions. Since the mid-50s of the last

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century to this day, large studies have been and are being carried out on the effect of elevated hardening temperatures on the phase composition, the structure of new formations, the degree of hydration of the binder, and the exotherm of cement.

The international conference RILEM, held in 1964 in Moscow, made a great contribution to the problem. There were made a number of reports on the choice of cement for heat treatment, the processes of hydration of Portland cement during heat and moisture treatment, reduction of concrete hardening time, temperature gradients in concrete exposed to steaming hardening of concrete in the conditions of Central Asia.

In a hot climate, the high temperature of the outside air (30... .35 °C) is observed 6...7 months a year. Under such conditions, the temperature of the concrete mixture at the moment of molding reaches 25 ... 30 °C. However, at present, these factors are not taken into account when setting the modes of heat and moisture treatment of concrete, as a result, the duration of heat and moisture treatment and energy consumption at enterprises in the southern and northern regions remain the same.

In order to study the influence of the initial temperature of the concrete mixture and the ambient temperature on the modes of heat and moisture treatment of concrete, we carried out a number of studies

II. Method

Portland cement (R_{ts}=40.8 MPa, S_{sp}=3357 cm^2/g) and slagportland cement (R_{ts}=33.8 MPa, S_{sp}=2593 cm^2/g) were used as binder. The filler was granite crushed stone with a maximum size of 20 mm and quartz sand with M_k=1.88. The composition of concrete on portland cement 1: 2.69: 4.58, on slagportland cement 1: 2.37: 4.1. The experiments were carried out in a climatic chamber. The initial temperature of the concrete mixture was taken equal to 15..20, 20 ... 25 and 25 ... 30 oC. A concrete mixture with a temperature of 20 ... 30 °C was prepared with heated water. However, after several tests, a slight decrease in concrete temperature was observed during preliminary curing. It turned out that at the time of preparation, only the mortar part of the concrete was heated. The coarse aggregate warmed up slowly, absorbing heat during the pre-holding, causing the temperature to drop. Considering this, in the future, the large aggregate and the metal mold were heated up to 30 ... 35 °C.

Then the concrete mixture was quickly placed in a mold, compacted by vibration and placed in a climatic chamber. The temperature of the freshly made concrete mixture was measured with a laboratory thermometer and an ETP-M device. Chromel- Copel thermocouples were installed at characteristic points of the sample. The samples were kept for 2 hours at a temperature of 25 ... 35 °C (depending on the initial temperature of the concrete mixture) and a relative humidity of 45 ... 50%. After preliminary holding, the samples were steamed in the same chamber.

The temperature rise for all series of experiments was 3 h at an average rate of 20°C/h, the duration of isothermal heating for concrete on portland cement-2; 4; 6, and on slag portland cement-4; 6; 8 hours. The concrete was cooled for 4 hours at an average rate 10 °C/h using a fan or kept for 6 h with an open control gate of the ventilation duct. The maximum temperature of isothermal heating of concrete samples on Portland cement-80, on slag Portland cement-90 °C.

A KSP-4 device was used to measure and record the temperature in the chamber and in the sample sections. The control and regulation of the temperature in the chamber was carried out

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automatically by the PRTE-2M software controller. In all experiments, the camera load factor was the same. For the reliability of the results, each series of experiments was repeated several times.

Samples - cubes with an edge of 10 cm were tested for compressive strength 4 h after heat and moisture treatment and after 3 and 28 days. For each batch of the same batch, three samples were molded, which were stored in a normal hardening chamber and tested after 28 days

III. Results And Discussion

The research results showed that the initial temperature of the concrete mixture significantly affects the nature of the increase in the strength of concrete prepared on portland cement (table-1).

The higher the initial temperature of concrete, the greater the strength it gains after heat and moisture treatment. However, after 3 days, the strength of concrete with different initial temperatures leveled off, and after 28 days, concrete gained the same strength regardless of the initial temperature (Fig). This, apparently, is explained by the fact that in concrete with a higher strength after heat and moisture reatment, its further growth occurs more slowly than in concrete with a lower strength. This is consistent with the kinetics of cement hydration. In concretes with greater strength, after heat and moisture treatment, a significant part of the cement grains is hydrated, and around the unhydrated core of the grains, denser shells are formed from the products of cement hydration. These shells further, during hardening, impede the penetration of moisture to the unhydrated parts of the cement grains, slowing down the hardening process. Hence it follows that the greater the strength of concrete after heat and moisture treatment, the less its further growth.

Table 1. Strength of concrete on portland cement under various modes of heat and moisture treatment

Ver-sions	№ Series	Environment parameters in the chamber during preliminary exposure		Initial temperature of concrete mix $T_{c.m.}$, °C	W/C	Cone draft, sm	Steaming mode, hour	Compressive strength of concrete, MPa through			
		t, °C	φ, %					4 hours after TBO	3 days	28 days	28 days normal hardening
1	2	3	4	5	6	7	8	9	10	11	12
I	1	15-16	70-75	15	0,65	2-2,5	2+3+6+4	17,4 61	20,3 71	26,8 94	28,5 100

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	2	20-21	70-75	20	0,65	2-2,5	2+3+6+4	18,6 60	22,2 72	29,1 94	31,1 100
II	3	26-28	48-50	22-25	0,65	2-2,5	2+3+6+4	20,5 65	22,1 70	29,4 94	31,4 100
	4	26-28	48-50	22-25	0,65	2-2,5	2+3+4+4	17,6 57	21,8 69	30,1 95	31,6 100
	5	26-28	48-50	22-25	0,65	2-2,5	2+3+2+4	*15,5* *49*	20,1 14	28,5 91	31,4 100
	6	26-28	48-50	22-25	0,65	2-2,5	2+3+2+6*	15,1 60	18,2 72	24,8 98	25,3 100
	7	26-28	48-50	22-25	0,65	2-2,5	2+3+2+6*	*17,4* *55*	21,5 72	29,5 93	31,8 100
III	8	32-34	44-46	28-30	0,65	1,5-2	2+3+4+4	19,7 54	22,5 70	30,1 94	32,0 100
	9	32-34	44-46	28-30	0,65	1,5-2	2+3+2+4	17,4 54	22,2 69	31,0 96	32,2 100
	10	32-34	44-46	28-30	0,65	1,5-2	2+3+6+4	23,2 70	25,5 77	31,5 95	33,0 100
	11	32-34	44-46	28-30	0,65	1,5-2	2+3+4+6*	21,0 68	22,5 73	29,8 96	31,0 100

*Notes. 1). Above the line is the strength of concrete, MPa, below the line -% 2). 6 * Cooling of concrete at an average rate of 3-4 °C/hour for 6 hours was carried out with an open regulating gate of the ventilation duct of the chamber. 3). Concrete in series 1 and 2 are prepared without water heating, i.e. according to conventional technology and pre-conditioned in the workshop for 2 hours under the conditions specified in the table.*

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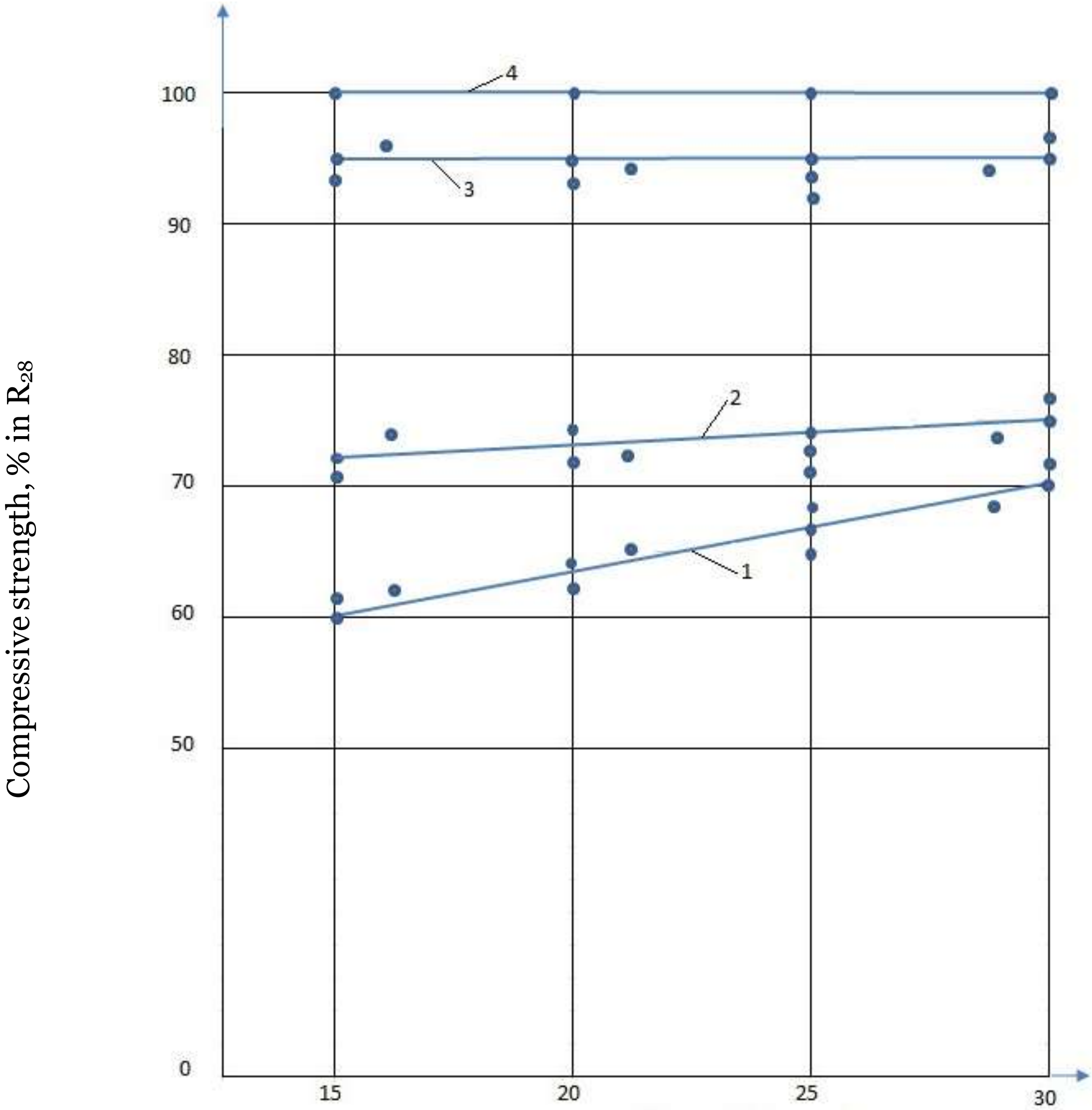

Initial temperature of the concrete mix, °C

Figure 1: The nature of the increase in the strength of concrete on Portland cement, depending on the initial temperature of the concrete mixture, which underwent heat treatment according to the mode of 2+3+6+4 hours.
1) concrete strength 4 hours after TVO; 2) also, after 3 days; 3) also after 28 days; 4) also after 28 days of normal hardening.

From table 1. It can be seen that for all series of experiments the 28-day strength of concrete on portland cement after heat and moisture treatment is 5-9% less than that of normal hardened concrete. The reason for the lack of strength can be two factors. First, heat treatment at high (80 °C) temperature. It is known that heat is a powerful factor in accelerating the hardening of concrete, but also to a certain extent disturbs its structure due to uneven expansion of the components. This leads to the appearance of stresses in the heterophase system, the appearance of cracks and other microdefects [12]. Secondly, preliminary curing of concrete at a relatively high ambient temperature (25-35°C). It was found [1] that the most favorable results are obtained after preliminary curing of freshly formed products on portland cement at a low temperature. Holding the concrete before heat treatment at a low temperature promotes a greater dissolution of silicate phases [2] and the formation of a smaller number of nucleating crystals but with a well-ordered structure and a high degree of solution saturation [13].

Thus, preliminary curing of concrete on portland cement at a relatively high ambient temperature, on the one hand, leads to a reduction in the preliminary curing time, an increase in the strength of concrete immediately after heat and moisture treatment, on the other hand, slowing down the further hydration of portland cement after heat and moisture treatment.

From table 1. It can be seen that for series 1 and 10, the heating mode, the temperature of isothermal holding and the duration of heat and moisture treatment are the same, but the strength indicators after heat and moisture treatment are different. In this case, the difference in strength indicators can be explained by the degree of maturity of the concrete, since its initial temperature was different and the heating time to the isothermal holding temperature was different.

Concrete with an initial temperature of 30 °C (series 10) is heated to the isothermal holding temperature for 4 hours, and with an initial temperature of 15 °C (series 1) for 5.5 hours. Accordingly, by the 4th hour of heat and humidity treatment, the number of degree-hours is 272 (series 10) and 162 (series 1).

As a result, by the end of the heat and moisture treatment, concrete with an increased initial temperature gains a large amount of degree-hours (series 10) compared to concrete with a lower initial temperature (series 1) and, accordingly, the strength indicators are 70 and 61% of R_{28nt}.

It should be noted that an increase in the initial temperature of the concrete mixture from 15 to 30 °C did not lead to a significant increase in the strength of concrete after heat treatment with portland slag cement (Table 2). This is apparently due to the property of the slag, which at relatively low positive temperatures does not show activity in the process of hydration. The unacceptability of slag portland cement for the preparation of warm concrete is also indicated in [14].

The difference between portland slag cement concrete in comparison with portland cement concrete is that the 28-day strength of portland slag cement concrete after heat and moisture treatment for all series of experiments exceeds the strength of the same concrete hardened under normal conditions (Table 2) by 10-20%. The data obtained are fully consistent with the results of [1], which notes that a high heating temperature (80-90 °C) not only provides high concrete strength immediately after heating, but also does not reduce further intensive growth of concrete strength on slag Portland cement.

From the test results (Tables 1 and 2) it can be seen that the nature of cooling significantly affects the strength of concrete after heat and moisture treatment. Concrete on portland cement with heat treatment modes 2 + 3 + 4 + 4 = 13 h (series 4, table 1) and 2 + 3 + 2 + 6 * = 13 hours (series 6 and 7, table 1) after heat and moisture treatment gain almost the same strength.

A similar effect is observed for concretes prepared on slag portland cement (series 4 and 6, Table 2). Equal strength indicators of concrete with different isothermal holding times are explained, apparently, by the same degree of maturity. For example, concrete heated according to the 2 + 3 + 6 + 4 h mode by the end of heat treatment gains the sum of degree-hours equal to 880;

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the same amount of degree-hours is gained by concrete subjected to heat treatment according to the 2 + 3 + 4 + 6 * h mode. The total duration of heat treatment in both cases is the same and amounts to 15 hours. But in the second variant, the isothermal holding time is reduced by 2 hours.

From the above, it follows that the increased temperature of the external environment has a beneficial effect on the individual stages of heat and moisture treatment. With an increase in the ambient temperature, the initial temperature of the concrete mix increases, which, at the same rate of temperature rise, contributes to a reduction in the time of this stage in comparison with concrete having a lower initial temperature. Cooling of concrete occurs more slowly due to a decrease in the temperature gradient between concrete and the environment, thereby it becomes possible to reduce the isothermal holding time.

Thermal holding of products after a short isothermal holding can be used especially effectively in hot climates. The increased temperature of the medium reduces heat loss through the enclosing structures of the chambers due to a decrease in the temperature gradient, providing a slower cooling of the products in the chamber. On the other hand, conditions are created for cooling products directly on the operating areas of the shops.

It is advisable to carry out heat and moisture treatment with thermos cooling (two-stage heat and moisture treatment) of products

according to two options, depending on the form of labor organization at precast concrete enterprises. If the molding equipment and heating units are assigned to the shift crew, it is advisable to cool the products in the heat and moisture treatment chambers. In the conditions of two-, three-shift operation, thermos cooling of products after isothermal holding is recommended to be carried out in ripening chambers, since in this case enterprises are interested in increasing the turnover of molding equipment and thermal units.

Table 2. Strength of concrete on slagportland cement under different modes of heat and moisture treatment

Options	№ Series	Environment parameters in thechamber during preliminaryexposure		Initial temperature of concrete mix $T_{c.m.}$, °C	V / C	Cone draft, sm	Steaming mode, hour	Compressive strength of concrete, MPa through			
		t, °C	φ, %					4 hours after TBO	3 days	28 days	28 days normal hardening
1	2	3	4	5	6	7	8	9	10	11	12
I	1	15-16	70-75	15	0,65	3-3,5	2+3+8+4	11,4 70	13,2 81	19,6 120	16,3 100
	2	20-21	70-75	20	0,6	3-	2+3+6+	9,6	11,	18,	15,2

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					5	3,5	4	63	8 77	0 118	100
II	3	26-28	48-50	22-25	0,6 5	3- 3,5	2+3+4+ 4	9,3 60	11, 0 71	16, 8 108	15,5 100
	4	26-28	48-50	22-25	0,6 5	3- 3,5	2+3+6+ 4	9,5 65	12, 1 83	17,1 117	14,6 100
	5	26-28	48-50	22-25	0,6 5	3- 3,5	2+3+8+ 4	12,5 72	14, 5 84	20, 7 10	17,2 100
	6	26-28	48-50	22-25	0,6 5	3- 3,5	2+3+4+ 6*	10,0 7 65	12, 5 81	18, 4 119	15,4 100
	7	26-28	48-50	22-25	0,6 5	3- 3,5	2+3+6+ 4	10,1 65	12, 5 81	17, 5 113	15,5 100
III	8	32-34	44-46	28-30	0,6 5	2,5- 3	2+3+8+ 4	12,5 71	14, 4 82	20, 0 114	17,6 100
	9	32-34	44-46	28-30	0,6 5	2,5- 3	2+3+6+ 4	10,6 67	13, 6 87	19, 0 121	15,6 100
	10	32-34	44-46	28-30	0,6 5	2,5- 3	2+3+4+ 4	9,5 61	11, 3 72	17,1 109	15,6 100
*Notes. one). Above the line - concrete strength, MPa, below the line -% 2). 6 * Cooling of concrete at an average rate of 3-4 ° C / hour for 6 hours is carried out with an open regulating gate of the ventilation duct of the chamber. 3). Concrete in series 1 and 2 are prepared without water heating, i.e. according to the usual technology and pre-conditioned in the shop for 2 hours under the conditions indicated in the table.*											

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The expediency of a two-stage heat and humidity treatment for the production of products in areas with hot climates was noted in [2].

Thus, the results of experimental studies prove the correctness of the assumptions on reducing the time of isothermal holding in the process of heat and moisture treatment of concrete in a hot climate. The purpose of the modes of heat and moisture treatment for each specific case, depending on the initial temperature of concrete and the environment, requires a special study. This is a laborious process, takes considerable time and is extremely inconvenient (and in many cases generally unacceptable) for production workers.

Therefore, we proposed an analytical method for optimizing the aging modes of products during heat treatment, taking into account the temperature of the environment, which is as follows.

The sum of degree - hours is determined for the accepted factory mode, where the temperature of the concrete mixture (t_{c1}) entering the heat treatment unit, according to the current standards, is + 15 ^{o}C:

$S_1=(t_{is}-t_{c1})(\tau_{lif}^1 / 2 + \tau_{is}^1)$, deg-hour;

Then the sum of the degree-hours of the same mode is determined, but with the actual initial temperature of the concrete (t_{c2}):

$S_2 = (t_{is} - t_{c2})(\tau_{lif}^2 / 2 + \tau_{is}^2)$, deg-hour;

The ratio of the latter to the former is the optimization factor:

$K_{op} = S_2/S_1$;

The duration of the active cycle of heat and moisture treatment of concrete, taking into account K_{op}:

$T_{op} = T_1 \cdot K_{op} = (\tau_{lif}^1 + \tau_{is}^1) \cdot K_{op}$, hour

The results of studying the modes of heat and moisture treatment of concrete with different initial temperatures of the concrete mixture and the obtained strength indicators of concrete after heat and moisture treatment confirmed the correctness of the proposed method for optimizing the modes of heat and moisture treatment in the manufacture of precast concrete products in hot climates

IV. Conclusion

An increased initial temperature (25 ... 30 °C) before heat treatment contributes to a more intensive increase in the strength of concretes during heat and moisture treatment, prepared with Portland cement. For concretes on slag portland cement, it has no noticeable effect.

The strength of concrete prepared on Portland cement and slag Portland cement is significantly influenced by the nature of cooling; cooling at an elevated temperature (35-40 °C) of the environment proceeds more slowly, reduces temperature gradients in the product, contributes to an increase in the strength of concrete immediately after heat and moisture treatment.

The increased temperature of the environment creates favorable conditions for two-stage heat and moisture treatment. This method is equally effective for concretes based on Portland cement and Portland slag cement.

The purpose of the modes of heat and humidity treatment of precast concrete products, taking into account the ambient temperature of a hot climate, makes it possible to reduce the active cycle time (temperature rise + isothermal heating) by 2 ... 3 hours. The decrease in energy consumption is 20 ... 22%.

References

1. Mironov S.A. Temperature factor in concrete hardening. -M.: Stroyizdat, 1948. - 236 p.
2. Mironov S.A., Malinina L.A. Acceleration of concrete hardening. - M.: Stroyizdat, 1961. - 224 p.
3. Рахимов А. М., Жураев Б. Г. Исследование температурных полей в процессе пропаривания и остывания бетонных изделий в условиях повышенных температур среды //Символ науки. – 2016. – №. 2-2. – С. 72-73.
4. Рахимов А. М., Жураев Б. Г., Хакимов Ш. А. Энергосберегающий метод тепловой обработки бетона в районах с жарким климатом //Символ науки. – 2016. – №. 4-3. – С. 63-65.
5. Фозилов О. К., Рахимов А. М. Пути снижения энергетических затрат при производстве сборных железобетонных изделий в районах с жарким климатом //Приоритетные направления развития науки. – 2014. – С. 73-75.
6. Рахимов А. М. и др. УСКОРЕНИЕ ТВЕРДЕНИЯ БЕТОНА ПРИ ИЗГОТОВЛЕНИИ СБОРНЫХ ЖЕЛЕЗОБЕТОННЫХ ИЗДЕЛИЙ //Conferencea. – 2022. – С. 20-22.
7. Рахимов А. М., Ахмедов П. С., Мамадов Б. А. РАЦИОНАЛЬНЫЕ ГРАНИЦЫ ПРИМЕНЕНИЯ РАЗЛИЧНЫХ МЕТОДОВ УСКОРЕНИЯ ТВЕРДЕНИЯ БЕТОНА С ТОЧКИ ЗРЕНИЯ РАСХОДА ЭНЕРГОРЕСУРСОВ //Science Time. – 2017. – №. 5 (41). – С. 236-238.
8. Рахимов А. М., Жураев Б. Г., Эшонжонов Ж. Б. ОСОБЕННОСТИ ТЕПЛОВОЙ ОБРАБОТКИ БЕТОНА В РАЙОНАХ С ЖАРКИМ КЛИМАТОМ //Вестник Науки и Творчества. – 2017. – №. 1 (13). – С. 96-98.
9. Рахимов А. М. и др. НЕКОТОРЫЕ АСПЕКТЫ ТЕПЛОВОЙ ОБРАБОТКИ БЕТОНА В РАЙОНАХ С ЖАРКИМ КЛИМАТОМ //Вестник Науки и Творчества. – 2017. – №. 3 (15). – С. 110-113.
10. Рахимов А. М., Мамадов Б. А. ЭНЕРГОСБЕРЕГАЮЩИЕ МЕТОДЫ УСКОРЕНИЯ ТВЕРДЕНИЯ БЕТОНА //НАУЧНЫЙ ЭЛЕКТРОННЫЙ ЖУРНАЛ «МАТРИЦА НАУЧНОГО ПОЗНАНИЯ». – С. 81.
11. Raximov, A. M., Alimov, X. L., To'xtaboev, A. A., Mamadov, B. A., & Mo'minov, K. K. (2021). Heat And Humidity Treatment Of Concrete In Hot Climates. *International Journal of Progressive Sciences and Technologies*, *24*(1), 312-319.
12. Muminov, K. K., Cholponov, O., Mamadov, B. A., oglu Bakhtiyor, M., & Akramova, D. Physical Processes as a Result of Concrete Concrete in Dry-hot Climate Conditions. *International Journal of Human Computing Studies*, *3*(2), 1-6.
13. Mamadov, B., Muminov, K., Cholponov, O., Nazarov, R., & Egamberdiev, A. Reduction of Destructive Processes in Concrete Concrete Processing in Dry-hot Climate Conditions. *International Journal on Integrated Education*, *3*(12), 430-435.
14. Muminov, K. K., Cholponov, O., Mamadov, B. A., oglu Bakhtiyor, M., & Akramova, D. Physical Processes as a Result of Concrete Concrete in Dry-hot Climate Conditions. *International Journal of Human Computing Studies*, *3*(2), 1-6.

Czech
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ISSN (E): 2788-0389
Website: www.peerianjournal.com
Email: editor@peerianjournal.com

15. Хакимов Ш. А., Муминов К. К. ОБЕЗВОЖИВАНИЕ БЕТОНА В УСЛОВИЯХ СУХОГО-ЖАРКОГО КЛИМАТА //НАУЧНЫЙ ЭЛЕКТРОННЫЙ ЖУРНАЛ «МАТРИЦА НАУЧНОГО ПОЗНАНИЯ». – С. 86.
16. Холбоев З. Х., Мавлонов Р. А. Исследование напряженно-деформированного состояния резаксайской плотины с учетом физически нелинейных свойств грунтов //Science Time. – 2017. – №. 3 (39). – С. 464-468.
17. Раззаков С. Ж., Холбоев З. Х., Косимов И. М. Определение динамических характеристик модели зданий, возведенных из малопрочных материалов. – 2020.
18. Mavlonov R. A., Numanova S. E. Effectiveness of seismic base isolation in reinforced concrete multi-storey buildings //Journal of Tashkent Institute of Railway Engineers. – 2020. – Т. 16. – №. 4. – С. 100-105.
19. Ризаев Б. Ш., Мавлонов Р. А., Нуманова С. Э. Деформации усадки и ползучести бетона в условиях сухого жаркого климата //Символ науки. – 2016. – №. 5-2. – С. 95-97.
20. Mavlonov R. A., Numanova S. E., Umarov I. I. Seismic insulation of the foundation //EPRA International Journal of Multidisciplinary Research (IJMR)-Peer Reviewed Journal. – 2020. – Т. 6. – №. 10.
21. Mavlonov R. A., Ergasheva N. E. Strengthening reinforced concrete members //Символ науки. – 2015. – №. 3. – С. 22-24.
22. Abdujabborovich M. R., Ugli N. N. R. Development and application of ultra high performance concrete //Инновационная наука. – 2016. – №. 5-2 (17). – С. 130-132.
23. Mavlonov R. A., Vakkasov K. S. Influence of wind loading //Символ науки: международный научный журнал. – 2015. – №. 6. – С. 36-38.
24. Numanova S. E. Energy-efficient modern constructions of external walls //Экономика и социум. – 2021. – №. 1-1. – С. 193-195.
25. Хамидов А. И., Нуманова С. Э., Жураев Д. П. У. Прочность бетона на основе безобжиговых щёлочных вяжущих, твердеющего в условиях сухого и жаркого климата //Символ науки. – 2016. – №. 1-2. – С. 107-109.
26. No‘Manova S. E. Ta'lim jarayonida talabalarning amaliy bilimlarini rivojlantirish metodikasi //Oriental renaissance: Innovative, educational, natural and social sciences. – 2021. – Т. 1. – №. 9. – С. 585-589.
27. No‘Manova S. E. Qurilish materiallari, buyumlari va konstruksiyalarini ishlab chiqarish //Oriental renaissance: Innovative, educational, natural and social sciences. – 2021. – Т. 1. – №. 9. – С. 605-608.
28. Мавлонов Р. А., Ортиков И. А. Sound-insulating materials //Актуальные проблемы научной мысли. – 2014. – С. 31-33.
29. Мавлонов Р. А., Ортиков И. А. Cold weather masonry construction //Материалы сборника международной НПК «Перспективы развития науки. – 2014. – С. 49-51.