Technobius, 2022, 2(3), 0022, DOI: https://doi.org/10.54355/tbus/2.3.2022.0022

Technobius

https://technobius.kz/

e-ISSN
2789-7338

Study of cement binders applicable for modified cast-in-place concrete

Khaidi Khonjo, Yerzhan Toleuov, Aizere Azbergenova, Akkumis Urumbayeva

Department of Construction and Building materials, Satbayev University, 22 Satbayev str., Almaty, Kazakhstan
*Correspondence: hhonjo0809@gmail.com

Abstract. This article presents the results of experimental studies of cement binder from local raw material bases optimal for the production of cast modified concrete (CMC). Having a special self-compacting nature, as well as a sensitive cost-effectiveness for the Kazakhstan concrete mixtures manufacturer, this type of concrete requires the use of cement with stable physical and technical characteristics. The study conducted an analysis of the nomenclature of local bases of cement raw materials, testing for cement fineness of Portland cement PC 400 D20 and compressive strength. It is revealed that in Kazakhstan there is a fairly wide range of cement products available with and without additives, produced by dry and wet method. Samples of Portland cement with mineral additives were taken for testing. According to the results of tests, the best indicators of grinding fineness 94.65% and compressive strength on 28 days 42.8 MPa were obtained for Portland cement with mineral additives of Bukhtarminskaya cement company LLP, produced by wet method.
Keywords: CMC, cement binder, Portland cement, compressive strength, raw materials.

1. Introduction

Modern monolithic house-building requires the use of an expanded range of commercial concrete products. In this regard, plants producing concrete mixtures are continuously engaged in optimization of the production process, involving leading concrete scientists, and implementing the results of their scientific and scientific-technical works [1-2]. For example, the authors of this study were faced with a number of applied problems, which allowed the plant Temirbeton-1 LLP (Almaty, Kazakhstan) to diversify its production. Diversification was subjected to the technological line of production of the widely used in Kazakhstan heavy concrete grade M350 class B25. The works were aimed at selection of compositions and development of cast modified concrete (CMC) technology. According to the literature, CMC is associated with the so-called self-compacting concrete (SCC). This concrete has a number of useful qualities, the main of which is the ability to compact under the action of its own weight [3]. The first steps in this direction were made by Japanese scientists in the 1980s. Since then, a lot of its modifications have been proposed, including the use of mineral additives from heavy industry waste [4-5]. Despite the fact that there have been many studies on CMCs, because of regional specifics, this area is still relevant, especially in Kazakhstan [6-7]. After all, an important factor determining the properties and quality of concrete and concrete mixes, as well as the continuity of their production is the availability of high-quality raw materials from local bases (as transportation of raw materials from abroad is likely to be unprofitable). Dynamic development of building materials market has a significant impact on the quality of raw materials supplied for concrete, necessitating continuous monitoring of their characteristics. And since cement is fundamental among them, control of its physical and technical characteristics requires special attention [8].

Portland cements with mineral additives not more than 20% by composition are accepted as binders for CMC [9], as other binders of cement group have a narrow focus of use. Mineral additives (e.g., fly ash) have a positive effect on the CMC, providing water retention and low segregation of the concrete mixture [5]. The main physical and technical properties of Portland cement, which should be paid keen attention to are the fineness and compressive strength at 28 days of hardening.

In this study the authors performed a comparative analysis of the basic properties of cement binder for CMC, presented by various manufacturers of local raw materials; considered the range of cement presented in the market and its physical and technical characteristics by conducting experimental studies.

2. Methods

To date, the leading manufacturers of cements in Kazakhstan that meet the requirements of [9] and [10] are:

1) "HeidelbergCement" group of companies (Heidelberg, Germany) [11], represented in Kazakhstan by the following organizations with a total staff of about 2,000 employees: plants of "Bukhtarminskaya cement company" LLP (Ust-Kamenogorsk); "Caspicement" LLP (Mangistau region); and "Shymkentcement" JSC (Shymkent); dealers and partners "Baykaz concrete" LLP (Almaty) and "Bektas group" LLP (Almaty), and others. Activity of HeidelbergCement is mainly connected with production and sale of cement, ready-mix concrete and aggregates. The list of products manufactured by these plants is given in Table 1 below.

Table 1 – Nomenclature of HeidelbergCement products in Kazakhstan [11]

Product name	Brand	Standard	Production type
Bukhtarminskaya cement company LLP (wet production)			
Portland cement with mineral additives	CEM II/A-S 42.5 H	GOST 31108-2003	Serial
	CEM II/A-S 32.5 H	GOST 31108-2003	On request
	CEM II/A-I 32.5 H	GOST 31108-2003	On request
	PC 400-D20	GOST 10178-85	Serial
Portland cement	CEM I 42.5 H	GOST 31108-2003	Serial
	PC 500 D0	GOST 10178-85	Serial
	PC 400 D0	GOST 10178-85	Serial
Portland cement of normalized composition	PC 500 D0-H	GOST 10178-85	Serial
	PC 400 D0-H	GOST 10178-85	On request
Portland sulfate-resistant cement	CEM I 42.5 H CC	GOST 22266-2013	Serial
Portland sulfate-resistant low-alkaline cement	CEM I 42.5 H CC NS	GOST 22266-2013	Serial
Composite cement	CEM V/A (S-P) 32.5 H	GOST 31108-2003	On request
Caspiycement LLP (dry production)			
Portland cement with mineral additives	CEM II/A-S 42.5 H	GOST 31108-2003	Serial
	CEM II/A-I 32.5 H	GOST 31108-2003	Serial
Portland cement	CEM I 42.5 H	GOST 31108-2003	Serial
Portland sulfate-resistant cement	CEM I 42.5 H CC	GOST 22266-2013	Serial
Portland cement for tamponage	PCT I-CC-100	GOST 1581-96	On request
Shymkentcement JSC (wet and dry production)			
Portland cement with mineral additives	PC 400 D20	GOST 10178-85	Serial
Portland cement of normalized composition	PC 500 D0-H	GOST 10178-85	Serial
Portland cement of normalized composition	PC 400 D0-H	GOST 10178-85	Serial
Portland slag cement	PSC 400	GOST 10178-85	Serial
	PSC 300	GOST 10178-85	Serial
Portland sulfate-resistant cement	PSRC 400 D0	GOST 22266-94	Serial
Portland cement for tamponage	PCT I-G-CC-1	GOST 1581-96	On request
		API Spec10A	On request

2) Steppe Cement LLC (Malaysia) [12], represented in Kazakhstan with a total staff of more than 1000 employees at the plant of Central Asia Cement JSC and its subsidiary Karcement JSC

(Karaganda region). The plant sells cement by the technology of dry method of production. The list of products manufactured by this plant is given in Table 2 below.

Table 2 – Nomenclature of JSC Karcement products [12]

Product name	Brand	Standard	Type
Portland cement of class 42.5 normal hardening	CEM I 42.5 H	GOST 31108-2003	Serial
Portland cement of class 42.5 quick-hardening	CEM I 42.5 B	GOST 31108-2003	Serial
Portland cement with slag from 6% to 20% of class 32.5 normal hardening	CEM II/A-S 32.5 H	GOST 31108-2003	Serial
Portland cement with slag from 21% to 35% of class 32.5 normal hardening	CEM II/B-S 32.5 H	GOST 31108-2003	Serial
Portland cement of grade 400	PC 400 D0	GOST 10178-85	Serial
Portland cement of grade 400 rationed	PC 400 D0 H	GOST 10175-85	Serial
Portland cement of grade 450 rationed (brand name)	PC 450 D0 H	GOST 10178-85	Serial
Portland cement of grade 400 with mineral additives up to 20%	PC 400 D20	GOST 10178-85	Serial
Portland slag cement of grade 400	PSC 400	GOST 10178-85	Serial
Portland slag cement of grade 300	PSC 300	GOST 10178-85	Serial

3) LLP "Standard Cement" (Shymkent) [13] with the number of employees more than 800. Production at the plant is carried out by dry method. The list of products manufactured by the plant is given in Table 2 below.

Table 3 – Nomenclature of Standard Cement LLP products [13]

Product name	Brand	Standard	Type
Portland slag cement of grade 400	PSC 400	GOST 10178-85	Serial
Portland cement of grade 400 with mineral additives up to 20%	PC 400 D20	GOST 10178-85	Serial
Portland cement of grade 400	PC 400 D0	GOST 10178-85	Serial
Portland cement of grade 400 rationed	PC 400 D0 H	GOST 10175-85	Serial
Portland cement	PC 500 D0	GOST 10178-85	Serial

In this study, a comparative analysis of the physical and technical characteristics was carried out only for Portland cement of grade 400 with mineral additives in the amount of 20%.

The determination of grinding fineness was carried out according to [14]. A sieve with a mesh size of 0.08 mm was used for the test (Figure 1). Portland cement samples prepared according to the requirements of [15] were dried at 105-110 °C for 2 h and cooled in a desiccator to prevent absorption of moisture by the material from the air. 50 g of each brand of Portland cement was passed through a sieve using a mechanical sieving device for 5-7 minutes at an accuracy of 0.05 g. This procedure was repeated until no more than 0.05 g of cement passed through the sieve. Control sieving was performed manually on paper for 1 min (Figure 2). The grind fineness of the cements was determined as the residue on the sieve as a percentage of the original sample weight to an accuracy of 0.1%.

Figure 1 – 0.08 mm sieve for determining cement fineness

Figure 2 – Portland cement weighing, passed through 0.08 mm sieve

To determine the compressive strength according to [16], 1.5 kg of sand conforming to [17], 0.5 kg of water and 0.2 kg of binder for each brand of Portland cement were selected. The W/C ratio was 0.4. First, the dry components were mixed for 2 minutes in the bowl of a paddle mixer (Figure 3). Then a well was made in the center of the dry mixture in which water was poured. After half a minute, the mixture was stirred for 1 minute (Figure 4).

Figure 3 – Automatic mixer

Figure 4 – Preparation of the mixture

Next, the mixtures were alternately poured into a cone mold to determine their flow, which should be between 106-115 mm. Otherwise, the W/C ratio should be changed upward or downward. The mixes with the appropriate cone flow (Figure 5) were excessively poured into the 40×40×160 mm beam specimen molds with three specimens for each test period. Compaction of the mixtures placed in the molds was performed on a vibroplatform for 3 minutes. After that, the excess of mixtures was removed flush with the edge of the mold.

Figure 5 – Cone flow

For the first 24 hours, the samples were stored at 90 % relative humidity and 20 ºC, and then they were unmolded and immersed in a bath of water to a depth of 2 cm at the same temperature (Figure 6).

Figure 6 – Steam chamber for thermal-moisture treatment of cement beams

When the storage time was reached, the specimens were removed from the bath and tested on an E 160 N press to determine the bending and compressive strength (Figure 7). The average rate of load build-up during the test was 2.0±0.5 MPa/s.

Figure 7 – Sample of a beam at 28 days of age to determine the bending strength (left) and compression strength (right)

3. Results and Discussion

The results of tests to determine the fineness of Portland cement 400 with 20 % mineral additive is shown in Figure 8 below.

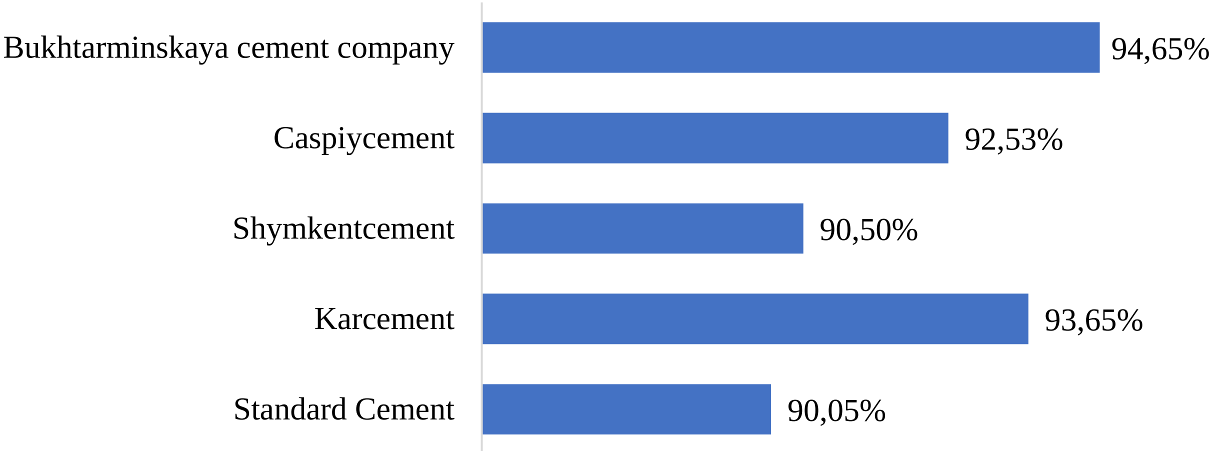

Figure 8 – Grinding fineness

The grinding fineness of the binder used in the design of compositions of cast concrete mixtures affects two factors:

- The higher the grinding fineness, the greater the unit surface area and the more intense the crystallization during hydration, hence the higher the strength characteristics of the final conglomerate;

- The higher the grinding fineness, the higher the water demand of the mixture, hence, the lower the strength characteristics.

The factors have directly opposite effects. However, the difference in grinding fineness of the cements under study has a small gap range. For this reason, a cement with greater grinding fineness is chosen as a binder, which will have little effect on the water demand of the mixture, but, when superplasticizers are used, will affect the strength characteristics in the direction of their increase. This choice is confirmed by the results of tests to determine the strength characteristics of cement at the age of 28 days (Figure 9).

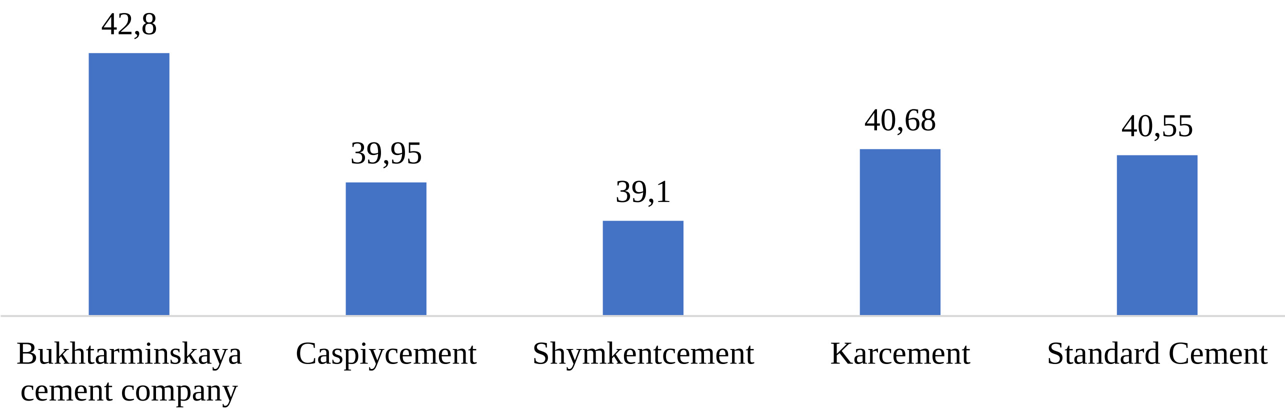

Figure 9 – Compressive strength at 28 days, MPa

According to test results, because of obtaining the highest binder strength indicators the most applicable is PC 400 D20 produced by "Bukhtarminskaya cement company" LLP.

For analysis of cements in order to select as a binder the tests carried out are sufficient. The results of these tests will make it clear which manufacturer's products are more suitable as a raw material component for the design of CMC compositions.

4. Conclusions

Analysis of the nomenclature of the considered suppliers of binders for concrete mixtures revealed a large variety of products offered, produced by both dry and wet method, with and without mineral additives. Based on the characteristics of CMC, Portland cement with mineral additives turned out to be the most optimal binder for its production. A comparative analysis of physical and technical characteristics of Portland cement PC 400 D20 from different local suppliers revealed the following:

1. Grinding fineness of the considered PC 400 D20 varies from 90.05 to 94.65 %;
2. Compressive strength of the considered PC 400 D20 ranges from 39.1 to 42.8 MPa;
3. According to both main parameters the leader is a PC 400 D20, produced by "Bukhtarminskaya cement company" LLP, which can be recommended for use in the production of CMC in the plant LLC "Temirbeton-1" in compliance with the rules and requirements for concretes of this type.

Acknowledgments

This study is based on research work of Associate Professor D.A. Akhmetov "Selection and placement of cast modified concrete of grade M350 with class B25 according to GOST 7473-2010", registered in the database of JSC "NCSTE" under the number № 0122РКИ0119 dated 30.06.2022.

References

1. The Effect of Low-Modulus Plastic Fiber on the Physical and Technical Characteristics of Modified Heavy Concretes Based on Polycarboxylates and Microsilica / D.A. Akhmetov, Y.V. Pukharenko, N.I. Vatin, S.B. Akhazhanov, A.R. Akhmetov, A.Z. Jetpisbayeva, Y.B. Utepov // Materials. — 2022. — Vol. 15, No. 7. — P. 2648. https://doi.org/10.3390/ma15072648
2. Effect of fine fillers from industrial waste and various chemical additives on the placeability of self-compacting concrete / Y. Utepov, D. Akhmetov, I. Akhmatshaeva // Computers and Concrete. — 2020. — T. 25, № 1. — C. 59–65. https://doi.org/10.12989/CAC.2020.25.1.059
3. Experimental study on rheology, strength and durability properties of high strength self-compacting concrete / S.D. Bauchkar, H.S. Chore // Computers and Concrete. — 2018. — Vol. 22, No. 2. — P. 183–196. https://doi.org/10.12989/CAC.2018.22.2.183
4. Effect of modifiers and mineral additives from industrial waste on the quality of aerated concrete products / Y. Sabitov, D. Dyussembinov, D. Bazarbayev // Technobius. — 2021. — Vol. 1, No. 4. — P. 0010. https://doi.org/10.54355/tbus/1.4.2021.0010
5. A review on performance of waste materials in self compacting concrete (scc) / I. Ismail, N. Jamaluddin, S. Shahidan // Jurnal Teknologi. — 2016. — Vol. 78, No. 5. https://doi.org/10.11113/jt.v78.8233
6. Determination of Optimal Fibre Reinforcement Parameters for Self-Compacting Concretes / D.A. Akhmetov, A. Aniskin, Ye.B. Utepov, Ye.N. Root, G. Kozina // Tehnicki vjesnik - Technical Gazette. — 2020. — Vol. 27, No. 6. — P. 1982–1989. https://doi.org/10.17559/TV-20200630163212
7. Effect of low-modulus polypropylene fiber on physical and mechanical properties of self-compacting concrete / D. Akhmetov, S. Akhazhanov, A. Jetpisbayeva, Y. Pukharenko, Y. Root, Y. Utepov, A. Akhmetov // Case Studies in Construction Materials. — 2022. — Vol. 16. — P. e00814. https://doi.org/10.1016/j.cscm.2021.e00814
8. Accounting of influence of quality of concrete raw components and of operating conditions on concrete products durability from the perspective of technical regulation / A. Gubskaya, A. Gapotchenko, T. Volovik // Problemy sovremennogo betona i zhelezobetona. — 2019. — No. 11. — P. 108–124. https://doi.org/10.35579/2076-6033-2019-11-08
9. Interstate standard GOST 10178-85 Portland cement and portland blastfurnace slag cement. Specifications [Electronic resource] / MEGANORM // MEGANORM. — [2021]. — Mode of access: https://meganorm.ru/Index2/1/4294853/4294853156.htm
10. Interstate standard GOST 30515-2013 Cements. General specifications [Electronic resource] / MEGANORM // MEGANORM. — [2021]. — Mode of access: https://meganorm.ru/Index2/1/4293771/4293771004.htm
11. Welcome to HeidelbergCement in Kazakhstan [Electronic resource] / HeidelbergCement. — [2022]. — Mode of access: https://kz.heidelbergcement.com/en (accessed date: 29.08.2022).
12. Central Asia Cement [Electronic resource] / CAC. — [2022]. — Mode of access: https://cac.kz/products/ (accessed date: 29.08.2022).
13. Standard Cement [Electronic resource] / SC. — [2022]. — Mode of access: http://standard-cement.com/ (accessed date: 29.08.2022).
14. Interstate standard GOST 310.2-76 Cements. Methods of grinding fineness determination [Electronic resource] / MEGANORM // MEGANORM. — [2021]. — Mode of access: https://meganorm.ru/Index/34/34110.htm
15. Interstate standard GOST 310.1-76 Cement. Test methods. General [Electronic resource] / MEGANORM // MEGANORM. — [2021]. — Mode of access: https://meganorm.ru/Index2/1/4294853/4294853170.htm
16. Interstate standard GOST 310.4-81 Cements. Methods of bending and compression strength determination [Electronic resource] / MEGANORM // MEGANORM. — [2021]. — Mode of access: https://meganorm.ru/Index2/1/4294853/4294853167.htm
17. Interstate standard GOST 6139 Sand for cement testing. Specifications [Electronic resource] / MEGANORM // MEGANORM. — [2021]. — Mode of access: https://meganorm.ru/Index2/1/4293719/4293719479.htm

Information about authors:

Khaidi Khonjo – Master Student, Department of Construction and Building materials, Satbayev University, 22 Satbayev str., Almaty, Kazakhstan, hhonjo0809@gmail.com

Yerzhan Toleuov – Master Student, Department of Construction and Building materials, Satbayev University, 22 Satbayev str., Almaty, Kazakhstan, yer-zhan@mail.ru

Aizere Azbergenova – Master Student, Department of Construction and Building materials, Satbayev University, 22 Satbayev str., Almaty, Kazakhstan, aizeinelkhan@gmail.com

Akkumis Urumbayeva – Master Student, Department of Construction and Building materials, Satbayev University, 22 Satbayev str., Almaty, Kazakhstan, urumbayevaakkumis@gmail.com