Physical and mechanical properties of Portland cement clinkers from raw materials of Karakalpakstan

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Abstract. In this article, the development of a technology for the production of clinkers and cements based on them using previously unexplored alternative sources of local raw materials in Karakalpakstan is studied, is an effective solution to the problem of covering the cement industry's construction industry needs. Development of practical recommendations on the technology for obtaining Portland cement clinkers and cements based on the raw materials of Karakalpakstan. The study of the chemical and mineralogical composition of the raw materials of Karakalpakstan with the aim of their application to obtain high-quality clinkers and cements based on them. For raw mixes, which include limestone from the Dzhamansay-2 deposit, the clay component of the Berkuttau site, an iron-containing cinder from Almalyk mining-and-metallurgical integrated works, and gypsum stone from the Northern Dzhamansay deposit, the optimal firing temperature is 1450 °C, which corresponds to the classical temperature index Portland cement clinker production. Raw mixtures based on the tested raw materials are highly reactive. When firing two-component feed mixtures using limestone of the Dzhamansay-2 deposit and basalt rock of the Berkuttau section, the optimum clinker sintering interval is 1400-1420 °C. Physical and mechanical tests have established that, on the basis of the tested raw materials (limestone of the Dzhamansay-2 deposit, the clay component of the Northern Dzhamansay deposit, the basaltic rock of the Berkuttau site and iron-containing additives), clinkers can be produced for general construction and sulfate-resistant cement grades of at least "400", according to technological indicators fully meeting the requirements of State standard 10178; State standard 30515 and State standard 222 66.

1. Introduction

The northernmost territory of Uzbekistan is the Republic of Karakalpakstan, which occupies a vast territory, characterized by a variety of climatic and geographical conditions. Due to the drying of the Aral Sea, the region is characterized by high salinity of soil and subsoil waters. Given the above factors in this region, it is advisable to use building materials that are resistant to the effects of mineral salts and climatic variations. The emergence of local producers will eliminate the transport margin and make cement more affordable and cheaper.

At the same time, it should be noted that the republic is rich in raw materials suitable for the production of high-quality cement and other types of construction products, the concept of development of Karakalpakstan is aimed at increasing the number of them. To create the technological basis for the construction of new cement plants in the northern region, it is necessary to conduct
complex technological tests of the cement raw materials of existing deposits with the issuance of optimal chemical and technological parameters for the formation of the composition of the raw mixes and their firing modes.

2. Methods

Chemical analysis of raw materials, raw mixes, and firing products was performed following the requirements of STATE STANDARD 5382-91 “Cements and materials of cement production. Chemical analysis methods” [1].

To grind the raw mixes, a laboratory ball mill was used when loading “grinding media: milled material = 3.5: 1”. The fineness of grinding of raw mixes was determined following the requirements of STATE STANDARD 310.2-76 “Cements. Test methods” [2]. Raw mixtures were fired in a laboratory silica furnace. The temperature during firing was controlled by a TPR thermocouple with a secondary device. The grinding of experimental clinkers for cement was carried out in a laboratory ball mill MBL when loading “grinding media: grinding material = 5.5: 1. Assessment of the quality of raw materials for the production of clinkers was carried out following the requirements of O’z DST 2950: 2015 “Raw materials for the production of Portland cement clinker. Technical conditions” [3].

Quality assessment of gypsum stone used in grinding O’z DST 760-96 “Gypsum and gypsum-anhydrite stones for the production of cementitious materials. Technical conditions” [4].

Physico–mechanical properties and chemical composition of the experimental cements were classified according to the requirements of STATE STANDARD 10178-85 “Portland cement and slag Portland cement. Technical conditions”, STATE STANDARD 30515-97 “Cements. General specifications” and STATE STANDARD 22266-94 Cement sulfate – resistant technical condition [5, 6].

The physico-mechanical properties of the obtained Portland cement clinkers are determined according to STATE STANDARD 10175-85, 310.1-310.3-76, 310.4-80 “Cement, methods of physical and mechanical tests” [2].

3. Results

The chemical and mineralogical compositions of technological samples of limestone of the Dzhamansay-2 deposit, the clay component of the Northern Dzhamansay deposit, the basaltic rock of the Berkuttau section and the gypsum stone of the Severny Jamansay deposit were established. The compositions of raw mixes and clinkers were calculated for general construction and sulfate-resistant cements based on the tested raw materials and iron-containing component - Almalyk mining-and-metallurgical integrated works cinder. The reactivity of raw mixes was determined and compositions for technological tests were optimized. Using raw mixes of optimal compositions (two-component: limestone, basalt rock and three-component: limestone, clay component, cinder), experimental clinkers were synthesized for general construction and sulfate-resistant cements [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20].

The chemical and mineralogical composition of clinkers is determined.

For firing experimental batches of clinkers, raw mixes of compositions # 2 and # 16 were prepared, the technological characteristics of which are given in Table. 1.
After dosing and homogenizing the components, the raw mixes # 2 and # 16 were moistened to (8-10)% and granulated. The granule samples after drying at (100-105) ° C were fired in a silica furnace under optimal temperature conditions with a 30-minute exposure: the interval for firing the raw mix # 2 (1400-1420) ° C; the interval for firing the raw mix # 16 (1430-1450) ° C. The firing temperature was measured with a TPR thermocouple with the temperature recorded on a secondary device. After firing, the granules were removed from the furnace for rapid air cooling. The quality of the firing products (experimental clinker # 2 and # 16) was controlled by the content of free calcium oxide, which was determined by the alcohol-glycerate method according to STATE STADARD 5382. In averaged samples of experienced clinkers experimentally established: free calcium oxide content: - in clinker # 2 - 0.05%; - in clinker # 16 - 0.10% the content of chlorine ion determined following STATE STADARD 5382:

- in clinker # 2 - 0.05%; - in clinker # 16 - 0.06%

To determine the physico-mechanical properties of the experimental cements from clinker batches # 2 and # 16 in the MBL laboratory mill with the addition of 5% gypsum stone from the Northern Jamansai deposit, experimental cements # 2 and # 16 were ground. The chemical composition of the gypsum stone from the Northern Jamansai deposit used in cement grinding fully complies with O'z DST 760.

Physico-mechanical properties of experimental cements # 2 and # 16 are determined following the requirements of STATE STADARD 310.1-310.4.

Protocols of physical and mechanical tests of experimental cements # 2 and # 16. Technological characteristics of experimental cements # 2 and # 16 and their physical and mechanical properties are given in Table 2.

Table 2. Technological characteristics and physico-mechanical properties of experimental cements

| Name of samples | SO3 content, % | Normal cement density test, % | Water-cement factor of solution 1: 3 | Signs of false setting | The timing setting Start, h-min | the end, h-min | Tensile strength at bending / compression, MPa, at the age of 28 days of normal hardening |
|-----------------|----------------|-------------------------------|-------------------------------------|-----------------------|-------------------------------|---------------|------------------------------------------------------------------|
| Experienced cement # 2 | 2.20           | 27.0                          | 0.40                                | is absent             | 2-50                          | 4-30          | 6.0 / 41.4                                                       |
| Experienced cement # 16 | 2.15           | 27.0                          | 0.39                                | is absent             | 3-00                          | 4-55          | 6.0 / 40.6                                                       |

The data from Table 2 show that experimental cements # 2 and # 16 in terms of SO3, chlorine ion, fineness, water requirements, and setting time meet the requirements of STATE STADARD 10178, STATE STADARD 30515, STATE STADARD 22266. Chlorine content (0.05-0.06) % in experimental cements does not exceed the indicator (0.10%), regulated by STATE STADARD 30515.

Tests for the uniformity of changes in the volume of cement paste samples from experimental cements passed [21 – 25].
There are no signs of false setting in cements. Experimental cements # 2 and # 16 at 28 days of normal hardening have a compressive strength of (41.4–40.6) MPa, respectively, which exceeds the regulated index for cement of the 400 grade (39.2 MPa).

Physical and mechanical tests have established that, on the basis of the tested raw materials (limestone of the Dzhamansay-2 deposit, the clay component of the Northern Dzhamansay deposit, the basaltic rock of the Berkuttau site and iron-containing additives), clinkers can be produced for general construction and sulfate-resistant cement grades of at least “400”, according to technological indicators fully meeting the requirements of STATE STADARD 10178; STATE STADARD 30515 and STATE STADARD 22266.

4. Conclusions
Technological tests established that the limestone of the Dzhamansay-2 deposit, the clay component of the North Dzhamansay deposit and the basalt rock of the Berkuttau section in terms of chemical composition fully comply with O’z DSt 2950 requirements and are suitable for use as raw materials in the production of Portland cement clinkers for general building cements following STATE STADARD 10178 and sulfate-resistant following STATE STADARD 22266 grades for compressive strength of at least “400”.

The limestone of the Dzhamansay-2 deposit, the clay component of the North Dzhamansay deposit, and the basaltic rock of the Berkuttau site, together with the iron-containing component and gypsum stone of the Northern Dzhamansay deposit, is recommended for use as a raw material in the production of clinkers and cements.

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