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Advancements in Expanded Clay Manufacturing Using "Clay-Desert Sand-Oil Sludge" Sludge Composite Materials

Kemajuan dalam Pembuatan Tanah Liat yang Diperluas Menggunakan Bahan Komposit "Tanah Liat-Pasir Gurun Pasir-Lumpur Minyak"

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Abstract

This study explores the development of resource-saving expanded clay technology utilizing underutilized clay raw materials and oil extraction waste. Traditional expanded clay production is energy-intensive and often employs high-quality clay; however, our research identifies technological modes and parameters for producing expanded clay through plastic molding, incorporating substandard raw materials and oil sludge. This method eliminates the need for costly energy-releasing additives and reduces energy costs associated with drying and firing by 25-30%. The research aims to demonstrate the feasibility of this novel production technique in the Republic of Kazakhstan, considering the local availability of raw materials, energy resources, and regional demand for thermal insulation materials in industrial and civil construction. Our findings suggest that integrating 'Desert Sand-Oil Sludge' into the batch composition can effectively produce granulated porous thermal insulation material, aligning with the region's development strategy and offering significant economic and environmental benefits.

Highlights:

- Resource Utilization: Uses oil waste and substandard clay to produce expanded clay, reducing reliance on high-quality materials.
- Energy Savings: Cuts energy costs for production by 25-30% through innovative processing.
- Regional Benefit: Aligns with Kazakhstan's strategy by utilizing local resources and supporting construction needs.

Keywords: Expanded Clay, Oil Sludge, Desert Sand

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Introduction

Traditionally, the raw materials for the production of expanded clay are sedimentary clay rocks. Most suitable are montmorillonite and mica clays containing no more than 30% quartz [1]. It is known that in many CIS Republics, nearby raw material deposits already worked out or their extraction is accompanied by increasing the depth of occurrence, waterlogging, complicating geological conditions, and increasing the delivery arm due to the distance of explored but not yet involved in the technological process reserves. This leads to a significant increase in the cost of expanded clay [2].

The need to replace raw material sources for the production of expanded clay also arises at the expanded clay plant in Kazakhstan, as the reserves of highly plastic montmorillonite clays are limited [3]. Importing the main raw materials, i.e., clay materials from other regions leads to an increase in the cost of finished products by more than 35%. Therefore, eliminating the increase in production costs at the expanded clay plant is possible by involving new types of raw materials that could replace clays near the production site [4]. From the variety of natural and technogenic raw material resources in Kazakhstan, weakly-expanding loess-like clays available in almost all regions are of the greatest interest for the production of expanded clay [5], [6]. The suitability of any clay raw material for the production of expanded clay is established by special research of its properties. The most important requirement for the raw materials is expansion during firing. Research in this direction is actively conducted abroad and described in the works of authors [7], [8].

The second requirement for the raw material is fusibility. However, due to the peculiarities of the chemical-mineralogical and instability of the chemical composition of loess-like clays, the firing of products does not ensure full expansion processes (t = 1180...1200 °C), which excludes the production of granulated porous materials like "expanded clay" without adjusting the component composition of the ceramic mass [9], [10]. Such raw material requires impoverishment or plasticization [11]. For example, studies conducted over bentonite clays of the Kazakh deposit have established that the tested clay in its natural state does not expand, however, the introduction of corrective additives slightly improves the expansion [12], [13].

Therefore, to obtain lightweight ceramic products with increased porosity and reduced thermal conductivity [14], pore-forming additives are introduced into the raw material mass - substances that dissociate at the firing temperature with the release of carbon dioxide (clay loam, gel, ground dolomite, chalk) as well as substances that burn out during firing (sawdust, cinder, ground coke, coke sludge, peat dust) [15]. However, the known fuel-containing additives in the form of coal, gas, diesel fuel, etc., used as energy carriers in the technology of construction ceramics are associated with high costs [16]. Therefore, it is of interest to consider as a puffing additive the waste from oil extraction and refining. For this, there are unlimited opportunities today since the resources of technogenic formations in the form of oil sludges and asphalt-resin-paraffin deposits, in particular at oil extraction enterprises, are sufficient [17]. According to studies, the "reserves" of oil sludges exceed 100 million tons in Russia, 20 million tons in Azerbaijan, 40 million tons in Kazakhstan, and 5 million tons in Ukraine [18].

In both domestic and foreign literature, there is a significant number of developments dedicated to the study of the technology of expanded clay based on well-, medium-, and weakly-expanding clays and loams [19]. In this case, the production of effective expanded clay based on weakly-expanding clays is resolved by adding burning additives such as fuel oil, coal, thermal power plant ash, etc. Studies by authors [20] are dedicated to the production of expanded clay using oil sludge waste and expanded clay concrete based on it.

Authors studied the physicochemical properties of oil sludges formed as a result of the industrial development of hydrocarbon raw material deposits in the South Turgay depression, containing mineral particles (50-75%), crude oil (20-40%), and water (5-10%), and methods for cleaning soils from oil contamination in the arid climate of the Republic of Kazakhstan [21]. They analyzed the influence of oil sludges on the physicochemical changes in the macro- and microstructure of foam concrete. It was determined that the organic part of the oil sludges is combustible and flammable, with a calorific value of 2500-3500 kcal/kg, which is equivalent to the calorific value of coal [22].

In work, the results of studies dedicated to the development of optimal compositions of raw material mixtures based on weakly-expanding clayey rock from the Kyzylorda region in the composition "oil sludge-desert sand" for obtaining granulated porous thermal insulation material of the type "expanded clay" are presented [23]. As a fuel-containing burning and strengthening additive to reduce energy costs and give maximum expansion and strength to the finished product, bottom oil sludge from the reservoirs of JSC "Petro Kazakhstan Kumkol Resources" and desert sand from the Kyzylorda deposit were used [24].

The goal of the study is to develop methods for managing the technological process of obtaining a conglomerate mixture "Desert Sand-Oil Sludge" [25] semi-finished product from loam and conglomerate mixture, and to develop technologies for the production of expanded clay based on them. Also, the selection of equipment according to the proposed technological scheme is carried out [26].

Methods

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The objects of study are the compositions and technology of thermal insulation material of the type "expanded clay" obtained on the basis of weakly-expanding loams and desert sand from the Kyzylorda deposit, using as a fuel-containing burning and expanding additive - oil sludge that is formed as a result of the industrial development of hydrocarbon raw material deposits in the South Turgay depression (on the example of JSC "Petro Kazakhstan Kumkol Resources") [27].

Results and Discussion

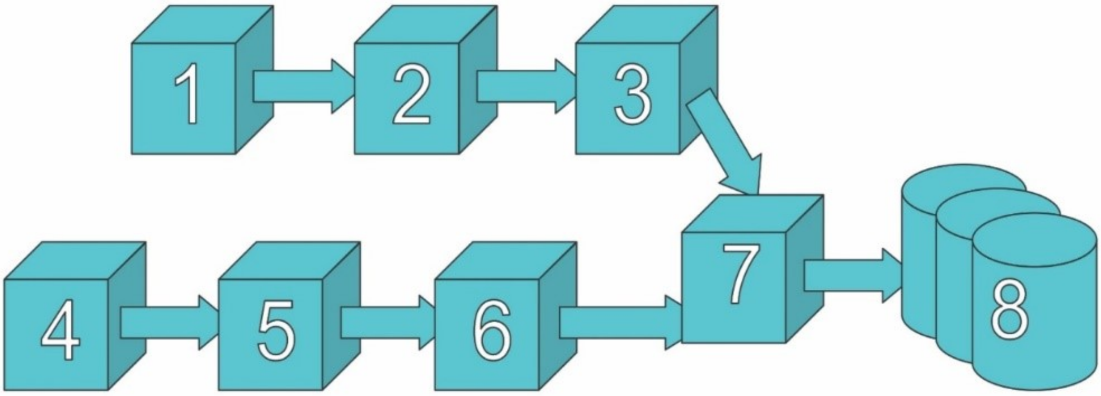

Figure 1. *Block Diagram of the Technological Process of Converting Oil Sludge*

Block diagram of the technological process of converting oil sludge into a conglomerate state: [28]

1. Container for oil sludge

2. Volume dosing (Volume doser)

3. Screw conveyor

4. Storage of desert sand raw material

5. Volume dosing (Volume doser)

6. Belt conveyor

7. Joint mixing (Twin-shaft mixer)

8. Bunker for organomineral conglomerate mixture

Thus, the proposed technological line for the production of expanded clay should include an additional line: [29]

1. Unit for preparing the conglomerate mixture "oil sludge-desert sand"

2. Warehouse for the conglomerate mixture "oil sludge-desert sand"

3. Mixing unit of the conglomerate mixture with loam to obtain ceramic mass

According to the proposed technology, drying and firing are carried out in two stages: the first stage - comparatively slow heating of granules to a temperature of 200-500°C and the second stage - rapid heating to a temperature of 1180-1200°C and maintaining at this temperature for 3-10 minutes. The quality of expanded clay gravel from weakly-expanding clays depends mainly on good homogenization of the clay mass with the conglomerate mixture "Desert Sand-Oil Sludge" before forming raw granules [30].

Conclusions

The developed technology for obtaining expanded clay using oil sludge is oriented towards the use of weakly-expanding and non-expanding clayey rocks of Kazakhstan. It was established that the physicochemical and technological properties of the raw materials used suggest choosing a plastic method of processing and forming expanded clay - as the most promising in terms of resource and energy efficiency. The selection of technological equipment for the production of expanded clay according to the proposed technology has been conducted. Implementing the developed expanded clay technology allows for the abandonment of costly energy-releasing additives and reduces energy expenditures for drying and firing products by 25-30%. A decisive factor in choosing the location for organizing expanded clay production is the availability of raw materials and sufficient energy resources, as well as the demand for the final product for industrial and civil construction, considering the development strategy of the Aral Sea region of the Republic of Kazakhstan.

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