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DEVELOPMENT OF ASH-SOIL COMPOSITE MATERIAL BASED ON WASTE FROM THERMAL POWER ENGINEERING

The article discusses the possibility of using ash from coal combustion at GRES-2 in the Pavlodar region to obtain ash-soil composite materials designed to strengthen the foundations of highways. The purpose of the study is to develop the composition of ash soil material with high physical, mechanical and operational characteristics. Within the framework of the study, the tasks were set to study the regularities of the formation of the structure of the material, as well as to develop the technology of its manufacture. The theoretical and practical significance of the work lies in the possibility of reusing industrial waste, reducing the environmental burden and the cost of building road infrastructure.

A review of domestic and foreign literature on the use of fly ash in the construction industry was also carried out. Particular attention in the literature review was paid to studies carried out in Kazakhstan, where there are significant volumes of ash waste from thermal power plants and state district power plants, especially in regions with a developed energy industry, such as Pavlodar, Karaganda and East Kazakhstan regions. The results of the analysis show the relevance of processing ash into building materials in order to improve the environmental and economic efficiency of road construction.

Keywords: fly ash, waste disposal, composite materials, industrial wastes, coal.

Introduction

The relevance of the topic is due to the need to solve environmental and economic problems associated with the utilization of ash generated in the process of coal combustion at thermal power plants. [1; 2]. In the Republic of Kazakhstan, as in many countries with developed energy sector, significant volumes of ash are generated annually, which are stored in ash dumps, occupying valuable land plots and harming the environment. [3]. At the same time, ash has a number of potentially useful properties that can be effectively used in the construction industry, especially in the production of road construction materials. [4;5].

The purpose of this work is to develop an ash-soil composite material with high physical and mechanical properties, suitable for strengthening the foundations of highways. The object of the study is the ash-soil materials of the Pavlodar region, and the subject is the development of an effective composition and technology for its manufacture.

The following tasks are considered in the work:

– to identify the patterns of formation of the structure and properties of ash-soil composites [6];

– to determine the influence of formulation and technological factors [7];

– to develop a technology for strengthening road bases using ash [8].

The scientific novelty lies in the theoretical substantiation and experimental confirmation of the processes of hardening and structure formation of ash soils by varying the composition, humidity and compaction pressure [9; 10]. The practical significance of the work lies in the creation of an environmentally friendly and cost-effective building material that contributes to the processing of industrial waste and improves the quality of road construction [11; 12].

Literature review

In recent years, there has been a steady increase in interest in the reuse of ash and ash and slag waste from thermal power engineering to create composite building materials. This is due to the environmental problems of waste disposal and the need to develop sustainable solutions in construction.

Thus, El Kanzaoui M. et al. [13] studied the physical and mechanical behavior of a new composite material based on ash from coal combustion at ultra-supercritical thermal power plants. The authors showed that properly modified ash can be used as an effective filler in composite matrices, demonstrating good thermal insulation and strength characteristics.

Saha M. [14] presented a systematic review of the literature on ash-based composites, focusing on the relationship between the structure, production

technology and properties of finished materials. The work highlights the potential to create a standardized classification of ash for engineering applications.

A study by Hosseinpour Sheikhrajab A. and Osmanlioglu A.E. [15] analyzed the effect of ash obtained at the Tunchbilek TPP on the properties of cement composites. The results showed that when replacing up to 30 % of cement with ash, strength characteristics improve, especially in the late hardening periods, due to pozzolanic reactions.

Kolokhov V. et al. [16] investigated the possibilities of secondary use of ash and slag from coal-fired thermal power plants in Ukraine in construction. They determined the optimal parameters for waste preparation and treatment, which improve adhesion to the cement matrix and increase resistance to external influences.

Islam M.R. et al. [17] proposed an innovative approach to soil stabilization using medical and coal ash in combination with plastic fibers. Their composites have shown increased bearing capacity and erosion resistance, which confirms the prospects of such solutions for road construction.

Methods and materials

To conduct the study, fly ash from coal combustion was used at the Ekibastuz GRES-2, located in the Pavlodar region. The ash was selected from the ash dump and pre-dried at room temperature. Local sandy and sandy loam soils that meet the requirements for use in road construction were used as a soil base.

Mixtures of ash and soil components were selected in different ratios (from 10 % to 50 % ash from the weight of the dry mixture) to determine the optimal composition. To improve the strength characteristics, binders were introduced into the composition: Portland cement and lime in small quantities (up to 10 %).

– Determination of the granulometric composition of ash and soil;

– Compression strength tests according to the GOST method after 7, 14 and 28 days of hardening;

– Determination of the density and moisture content of samples;

– Water and frost resistance tests to check the resistance of the material to weather conditions;

Study of the microstructure of the solidified material using a microscope (optical and/or electronic).

Samples were prepared by static compaction into cylindrical shapes, then kept under standard conditions (humidity 90–95 %, temperature +20–22°C). After that, laboratory tests were carried out to assess the physical and mechanical characteristics.

The use of such methods made it possible to assess how the properties of the material change with different proportions of ash and to select the composition that has the best strength and durability.

Results and discussion

Study of ash-soil compositions strengthened with binders. In the context of high costs for traditional road construction materials (cement, bitumen, crushed stone), the development of new building compositions using local resources and industrial waste is of particular relevance. Within the framework of this experimental work, the possibility of improving the physical and mechanical properties of soils with the use of fly ash and ash and slag mixtures (ASS) formed during the combustion of coals from the Ekibastuz deposit at the Ekibastuz GRES-2 was investigated.

The experiments were carried out on loam and sands from the Aksus deposit, which has a significant amount of raw materials for construction needs. The following binders were chosen:

– PC400-D20 Portland cement, which has high strength and a quick set of strength characteristics;

– Hydraulic quicklime with an active calcium oxide content of 65–70 %;

– Hardening activator – calcium chloride ($CaCl_2$), used to accelerate the hardening of compositions and increase their durability.

Improving the properties of loam using fly ash

At the first stage, the waterlogged loam was drained by introducing fly ash in an amount of 5 % to 30 % by weight. The results showed that an increase in the dosage of ash leads to a noticeable decrease in the moisture content of the material, which creates the prerequisites for its subsequent strengthening.

Strengthening loam with binders

In the second part of the experiment, the improved ash mixtures were strengthened with binders. It was found that the use of cement in the conditions of the northern regions of Kazakhstan requires increased dosages due to the deep seasonal freezing of soils. Therefore, the main emphasis was placed on the use of lime as a more economical and climate-adapted material.

To increase the hardening efficiency, 1 % of calcium chloride dissolved in the mixing water was additionally added to the lime ash mixture (with 25 % fly ash). The mixtures were subjected to compaction and hardening under conditions close to reality. The following characteristics were determined:

– Uniaxial compressive strength,

– Water resistance coefficient after water saturation,

– Frost resistance after freeze/thaw cycles,

– Optimal humidity and maximum density.

The composition (loam + ash) shows the lowest strength – 0.35 MPa, which is not enough for use in construction purposes.

The addition of lime significantly increases the strength to 1.04 MPa due to the formation of bonds between particles due to the pozzolanic-type reaction.

The combination of lime and $CaCl_2$ is even more efficient at 1.25 MPa, thanks to faster hardening and higher structure density.

The cement in the composition gives a strength of 1.38 MPa, confirming its active role in the formation of a strong binder.

The maximum strength of 1.60 MPa is achieved by using cement and $CaCl_2$ together, which provides both strength and accelerated hardening.

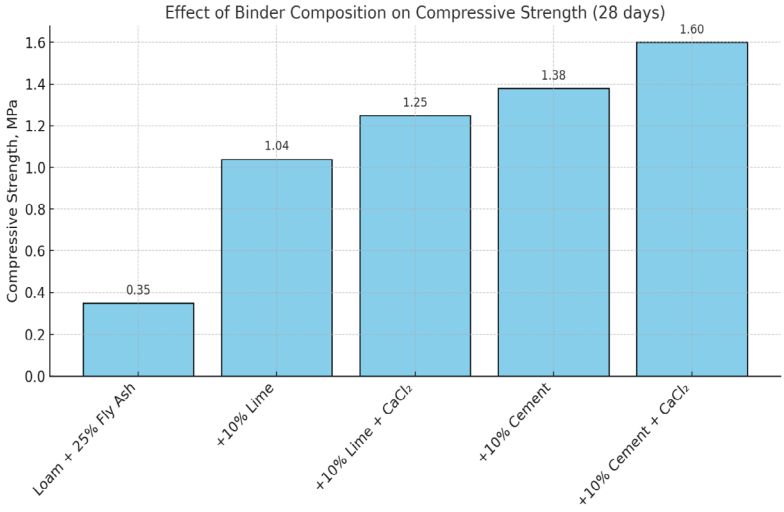

Figure 1 – Effect of the composition of sol-primers on strength after 28 days

The results showed that the addition of fly ash and reinforcement with lime with an activator can significantly improve the strength and frost-resistant characteristics of ash-soil compositions, making them suitable for use in the foundation of road structures of the IV road-climatic zone. Thus, the combination of local soils, ash and slag waste and available binders (Portland cement and lime) is a promising direction for the construction of inexpensive and durable road bases.

Conclusıons

1 The use of fly ash as a mineral binder in the composition of ash and soil mixtures makes it possible to effectively dispose of man-made waste and reduce the cost of building materials.

2 The combined use of $CaCl_2$ with lime or cement gives a pronounced synergistic effect – higher strength is achieved due to accelerated hardening and reduced porosity of the material.

3 The maximum strength (1.60 MPa) is obtained by using cement and $CaCl_2$, which indicates the prospects of this composition for load-bearing elements in low-rise construction and foundation construction.

Recommendations

1 To improve the strength characteristics of ash soils, it is recommended to use combined compositions based on ash, cement (6–8 %) and $CaCl_2$ (1–2%) as an activating additive.

2 The optimal ratio of components should be specified taking into account the characteristics of the local ash and soil, as well as the technological conditions of molding.

3 To accelerate strength gain in conditions of low temperature and humidity, it is advisable to use $CaCl_2$ as a hardening accelerator.

4 In the production of building blocks and foundation elements, use compositions with cement and $CaCl_2$ that provide a strength of more than 1.5 MPa.

5 Further research on the durability and water resistance of the developed compositions, including alternating freezing and thawing, is recommended to assess their suitability under different climatic conditions.

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ЖЫЛУ ЭНЕРГЕТИКАСЫ ҚАЛДЫҚТАРЫНАН КҮЛДІ ТОПЫРАҚ ҚҰРАМАЛЫ МАТЕРИАЛДАРЫН ӘЗІРЛЕУ

Мақалада Павлодар облысындағы ГРЭС-2-де көмірді жағудан алынған күлді автомобиль жолдарының іргетасын нығайтуға арналған күл-топырақ композиттік материалдарын алу үшін пайдалану мүмкіндігі қарастырылған. Зерттеудің мақсаты – жоғары физикалық, механикалық және эксплуатациялық сипаттамалары бар күл мен топырақ материалының құрамын жасау. Зерттеу шеңберінде материалдың құрылымының қалыптасу заңдылықтарын зерттеу, сонымен қатар оны жасау технологиясын әзірлеу міндеттері қойылды. Жұмыстың теориялық және практикалық маңыздылығы өндірістік қалдықтарды қайта өңдеу, экологиялық жүктемені және жол инфрақұрылымын салу шығындарын азайту мүмкіндігінде жатыр.

Сондай-ақ құрылыс индустриясында күлді пайдалану бойынша отандық және шетелдік әдебиеттерге шолу жасалды. Әдебиеттерді шолуда ерекше көңіл жылу электр станциялары мен мемлекеттік аудандық электр станцияларының күл қалдықтарының айтарлықтай көлемі бар Қазақстанда, әсіресе Павлодар, Қарағанды және Шығыс Қазақстан облыстары сияқты энергетикалық саласы дамыған аймақтарда жүргізілген зерттеулерге аударылды. Талдау нәтижелері жол құрылысының экологиялық және экономикалық тиімділігін арттыру мақсатында күлді құрылыс материалдарына өңдеудің өзектілігін көрсетеді.

Кілтті сөздер: күл, қалдықтар, композиттік материалдар, өнеркәсіптік қалдықтар, көмір.

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РАЗРАБОТКА ЗОЛОГРУНТОВОГО КОМПОЗИЦИОННОГО МАТЕРИАЛА НА ОТХОДАХ ТЕПЛОЭНЕРГЕТИКИ

В статье рассматривается возможность использования золы от сжигания угля на ГРЭС-2 Павлодарской области для получения зологрунтовых композиционных материалов, предназначенных для укрепления оснований автомобильных дорог. Цель исследования – разработка состава зологрунтового материала с высокими физико-механическими и эксплуатационными характеристиками. В рамках исследования поставлены задачи по изучению закономерностей формирования структуры материала, а также по разработке технологии его изготовления. Теоретическая и практическая значимость работы заключается в возможности вторичного использования промышленных отходов, снижении экологической нагрузки и затрат на строительство дорожной инфраструктуры.

Также был проведен обзор отечественной и зарубежной литературы по теме использования золы-уноса в строительной отрасли. Особое внимание в литературном обзоре было уделено исследованиям, выполненным в Казахстане, где имеются значительные объемы золоотходов от ТЭЦ и ГРЭС, особенно в регионах с развитой энергетической промышленностью, таких как Павлодарская, Карагандинская и Восточно-Казахстанская области. Результаты анализа показывают актуальность переработки золы в строительные материалы с целью повышения экологической и экономической эффективности дорожного строительства.

Ключевые слова: зола-унос, утилизация отходов, композиционные материалы, промышленные отходы, уголь.

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