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PRODUCTION OF PAVEMENT SLABS USING SEMI-DRY VIBRATION PRESSING TECHNOLOGY

Abstract. This article discusses the production technology of paving slabs using semi-dry vibration pressing. This technology is one of the most effective and cost-effective in the manufacture of small-piece concrete products. The use of a semi-dry concrete mix allows for high density, strength, and wear resistance of finished products. The simultaneous action of vibration and pressing ensures uniform distribution of the mixture and high-quality molding of the products. The paper provides a detailed analysis of the key parameters of the technological process: the composition and consistency of the concrete mix, compaction pressure, vibration frequency, and molding duration. Comparisons with other methods of paving slab production are provided, and the advantages of this method in terms of productivity, cost, and environmental safety are substantiated. Recommendations for process optimization and raw material selection are also offered to improve product quality and reduce costs. The research results can be used in practice by enterprises engaged in the production of paving slabs and other vibration-pressed building products. The article considers current problematic issues in the production of paving slabs using the semi-dry vibration pressing method, provides an overview of the process line, and analyzes the materials used. An assessment of the production problem area is provided. The results of the study are presented. The causes and consequences of using materials with specific characteristics and rheotechnological properties are identified.

Key words. Paving slab, vibration pressing, modulus of elasticity, strength class, frost resistance.

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ЖАРТЫЛАЙ ҚҰРҒАҚ ДІРІЛДЕТІП ПРЕСТЕУ ТЕХНОЛОГИЯСЫ АРҚЫЛЫ ТРАТУАР ПЛИТАЛАРЫН ӨНДІРУ

Аңдатпа. Бұл мақалада жартылай құрғақ діріл престеу арқылы тротуар плиталарын өндіру қарастырылады. Бұл технология ұсақ бетон бұйымдарын жасау үшін ең тиімді және үнемді технологияның бірі болып табылады. Жартылай құрғақ бетон қоспасын пайдалану дайын өнімдерде жоғары тығыздықты, беріктік пен тозуға төзімділікті қамтамасыз етеді. Діріл мен престеуді бір уақытта қолдану қоспаның біркелкі таралуын және өнімнің жоғары сапалы қалыптасуын қамтамасыз етеді. Жұмыста негізгі технологиялық параметрлердің егжей-тегжейлі талдауы берілген: бетон қоспасының құрамы мен консистенциясы, тығыздау қысымы, діріл жиілігі және қалыптау ұзақтығы. Жол төсемдерін өндірудің басқа әдістерімен салыстыру қарастырылған және бұл әдістің өнімділігі, құны және экологиялық қауіпсіздігі бойынша

артықшылықтары дәлелденген. Өнім сапасын жақсарту және шығындарды азайту үшін процесті оңтайландыру және шикізатты таңдау бойынша ұсыныстар да ұсынылады. Зерттеу нәтижелері тротуар плиталарын және басқа да діріл престелген құрылыс бұйымдарын өндірумен айналысатын компаниялардың практикалық қызметінде қолданылуы мүмкін. Жартылай құрғақ діріл престоу әдісін қолдана отырып, тротуар плиткаларын өндірудегі өзекті проблемалық мәселелер қарастырылады, өндірістік желіге шолу жасалады, сондай-ақ пайдаланылатын материалдар талданады. Өндірістегі мәселелердің проблемалық өрісіне баға беріледі. Жұмыстың нәтижелері ұсынылған. Біз белгілі бір сипаттамалары мен реотехнологиялық қасиеттері бар материалдарды пайдаланудың себептері мен салдарын анықтадық.

Кілт сөздер. тротуар плита, діріл престоу, жұқалық модулі, беріктік класы, аязға төзімділік.

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ПРОИЗВОДСТВО ТРОТУАРНЫХ ПЛИТ ПО ТЕХНОЛОГИИ ПОЛУСУХОГО ВИБРОПРЕССОВАНИЯ

Аннотация. В статье рассматривается технология производства тротуарных плит методом полусухого вибропрессования. Данная технология является одной из наиболее эффективных и экономически целесообразных при изготовлении мелкоштучных бетонных изделий. Применение полусухой бетонной смеси позволяет добиться высокой плотности, прочности и износостойкости готовой продукции. За счёт одновременного воздействия вибрации и прессования обеспечивается равномерное распределение смеси и качественное формование изделий. В работе подробно анализируются ключевые параметры технологического процесса: состав и консистенция бетонной смеси, давление прессования, частота вибрации и продолжительность формовки. Приводятся сравнительные характеристики с другими способами изготовления тротуарных плит, обосновываются преимущества рассматриваемого метода с точки зрения производительности, себестоимости и экологической безопасности. Также предложены рекомендации по оптимизации технологического процесса и подбору сырья с целью повышения качества продукции и снижения затрат. Результаты исследования могут быть использованы на практике в деятельности предприятий, занимающихся производством тротуарной плитки и других вибропрессованных строительных изделий. Рассмотрены актуальные проблемные вопросы производства тротуарной плитки методом полусухого вибропрессования, проведен обзор технологической линии, анализ используемых материалов. Дана оценка проблемной зоны производства. Представлены результаты работы. Выявлены причины и последствия применения материалов с определенными характеристиками и реотехнологическими свойствами.

Ключевые слова. Тротуарная плитка, вибропрессование, модуль упругости, класс прочности, морозостойкость.

Introduction. Since ancient times, people have laid roads for the convenience of moving between settlements and transporting various goods for trade. Since then, new materials have

appeared, such as asphalt, concrete, paving slabs, etc., and the need has turned into aesthetic needs, a person's desire to decorate a square, street or pedestrian area. Paving slabs and paving stones are ideal for satisfying such desires. Now it is probably impossible to imagine city streets, parks, squares, courtyards without paving stones. Its success and distribution are due to many properties:

- A cheaper alternative to asphalt and non-specific concrete slabs.
- A large number of different configurations in shape and color.
- Workability.
- Maintenance.
- Can be used in any conditions, etc.

A few years ago, consumers were satisfied with ordinary paving slabs of standard shape and gray color, but now the demand for something exclusive with a new color range is growing.

Materials and methods. Due to such popularity of paving slabs, many production facilities have appeared, among which it is necessary to compete. Even when producing the simplest tiles, a large list of questions and problems arises. Consider the production of classic gray paving stones (size does not matter, product thickness is 60 mm)

The complete production is located in the city of Uralsk. METALIKA (Serbia) is equipped with a production line for vibrating pressing. The line is equipped with a hopper with 2 compartments (Fig. 1), from which sand is fed along a belt to a mixer (Fig. 2), where the mixture is prepared and the humidity is recorded, then the mixture is fed by an automatic trolley into the hopper of the vibrating machine (Fig. 3), from where the finished, molded products are sent and the temperature is controlled. humidity treatment chamber (Fig. 5).



Figure 1 - Bunker.



Figure 2 - Mixer.



Figure 3 - Automatic trolley-type vibrating machine



Figure 4 - Carrier.



Figure 5- Humidity treatment chamber.

The first thing you need to pay attention to is the material: sand, cement, water and, possibly, some chemical additives. Starting with sand, you might think that everything is clear here, but there are a huge number of sand quarries and the material of each will have different characteristics. The most important indicators are the size class, size modulus and content. additives, clay, etc. It is important that the sand is coarse and uniform. This, first of all, significantly affects the strength characteristics of the product and, of course, changes its appearance, various additives are immediately noticeable, in “fine” sand the surface is smooth, but the strength and cement consumption are therefore unstable, while “coarse” sand gives a uniform expressive structure and stable strength characteristics. [1] (Fig. 6) sand 1 is shown with a density of $P=1800 \text{ kg/m}^3$ and sand 2 $P=1550 \text{ kg/m}^3$. It is important to remember that sand can freeze in winter or be covered with heavy snow, and not all quarries operate in winter.



Figure 6 - Sand used

The next important component that plays the role of a binder is cement. We use Portland cement CEM I 42.5H.[2] It, in turn, has many varieties and physicochemical indicators: the amount of mineral additives, the type of additive, the type of composition, the compressive strength class, the rate of increase in strength, etc. The initial indicator, of course, remains the strength class, but it is necessary to understand what is behind this characteristic. The increase in the main strength occurs within 28 days, but this is not a uniform process. Therefore, the manufacturer indicates the compressive strength of cement at the age of “2 and 28 days”. Of course, it is impossible to calculate exact numbers, so there is a certain tolerance for them. It is

also worth paying attention to the setting time. There are also chemical and mineralogical indicators of clinker, but most of them are not standardized.

Also, many manufacturers add various chemical compounds, in our case, Mursan BVA 19 is used. This is a water-reducing additive for concrete and mortar mixtures. It improves molding, compaction, frost resistance, front surface quality, reduces cement consumption, efflorescence and adhesion to equipment. The dosage can vary, but the average is 0.4% of the cement mass; for high-quality mixing, it is better to pre-mix with water. [4]

Despite the well-chosen materials, the following problems arise.

- Humidity. For consistent quality, it must be constant (we stick to 38%-39.5%). But due to the instability of its level in the sand, it is difficult to choose the right amount of water and the “chemistry” with it. High or low humidity can lead to sticking or poor formation of products = defective products. [2] The optimal solution was to install Hydronix; with this device, you can instantly monitor the humidity of the mixture and keep it within the specified limits. To solve the problem fundamentally, inert materials must have a closed warehouse that maintains a certain level of humidity regardless of external factors. MEST 17608-91 "Concrete paving slabs" states

The water-cement ratio of vibration-pressed products should not exceed 0.4. If the ratio is violated, water evaporates, voids appear, and strength characteristics decrease.



Figure 7 - Fault due to incorrect humidity.

- It takes place in a steam chamber. The main thing is that the humidity is not lower than 90%, since it directly affects the cement hydration process, in which water molecules combine with the molecules of cement components. Temperature plays a secondary role here, some manufacturers provide the necessary humidity

"Room" temperature, which also depends on the season. It is also important to keep the products for 2-3 hours before processing, otherwise "spider web" cracks will appear on the tile surface (Fig. 7). It is also necessary to ensure a uniform temperature rise. This period will allow to obtain the release strength (lower B22.5) on the 2nd day.[3]

Research materials and methods. Based on the results of all activities carried out from February 2025 to May of the same year, the following results were obtained:

- Having tried to process several types of sand, we settled on a quarry near the Samara-Shymkent highway. It met all the requirements, had a uniform structure, and most importantly, it positively affected the strength of the products.

- The minimum number of defects was achieved. The only remaining defects are related to various technical specifications. It is very important to choose the vibration suppression mode for the product with the selected compositions, depending on the configuration of the tile.[6]

- Reducing cement consumption while maintaining the required strength. According to the tests

09/10/21, the mixture contains 147 kg of cement, the actual concrete grade is B40. And the tests of 16.05.2022 also showed B40 with 110 kg of cement, according to MEST 10060-2012, the minimum strength class for group A is B22.5, so the cement reduction will continue.

- According to MEST 17608-2017[5]. For our climatic zone, a frost resistance class of F200 is required, according to the test results of 05.11.2024, the required class was achieved, of course, these indicators are sufficient, but we plan to see higher indicators. [7]

- Our products comply with the requirements of MEST for the remaining characteristics.

1 Table – Characteristics according to Interstate standard 17608-2017

№	Character	Group A	Group B	GroupC	GroupD
1	Compressive strength class, not less	B22,5	B25	B30	B40
2	Bending tensile strength class, not less than	Btd 3,2	Btd3,6	Btd 4,0	Btd 4,4
3	Degree of wear resistance, not more than	G3	G2	G1	G1
4	Minimum thickness of products, mm	40*	60*	80*	100*
5	The ratio of dimensions, not more than	--	12*	4*	2*

Conclusion. Using the example of the production of 60 mm thick gray tiles, we have considered the main areas of preparation. In order to obtain the highest possible quality tiles with low costs and a minimum number of defects, it is not enough to have high-quality materials; You always need to take into account many factors: the time of year, the capabilities and reliability of suppliers, the frequency and accuracy of maintenance, the technical characteristics of the equipment, the responsible personnel, a qualified repair team, the availability of necessary spare parts that cannot be purchased in a short time, and many other important details.

Of course, contact with other manufacturers can prevent some problems, but much remains strictly individual, and finding a solution can take a lot of time, which is a large number of experimental batches, their implementation is problematic and can negatively affect the reputation of the organization.

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