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FROM EXPERIENCE OF PREPARATION BASES UNDER CLAY SOILS OF MOTORWAYS AND BUILDINGS WITH LIME PILLING

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Abstract. Techniques of bases improvement with weak water-saturated clay soils by compaction with the help of lime with the purpose of formation their necessary building properties piles are considered. Positive examples of lime piles use in industrial and transport construction are given. Different techniques at the stages of work on the construction of piles and formation of compacted soil bases (the combination of soil compaction with lime piles with the further arrangement of additional embankments and compaction with heavy ramming) allow to provide construction on soils hardened in this way with a limitation of the permissible deformations of the structures erected on them. The most acceptable for technological and economic reasons are the types of air lime used for the installation of lime piles. The presented characteristics of the lime of regional producers of the Odessa region allow on the basis of a feasibility study to choose a more optimal version of the lime supplier for the device of lime piles on an industrial scale. According to the presented data, the most high-quality products are produced at the Kodyma factory of building materials. To obtain the required quality characteristics of other regional producers, additional purification of raw materials from impurities is required.

Keywords: lime piles, water-saturated clay soils, bases of embankments.

З ДОСВІДУ ПІДГОТОВКИ ОСНОВ ПІД ҐРУНТОВІ НАСИПИ АВТОДОРІГ ТА БУДІВЕЛЬ З УЛАШТУВАННЯМ ВАПНЯНИХ ПАЛЬ

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Анотація. Розглянуті способи і технологічні особливості підготовки основ зі слабких водонасичених глинистих ґрунтів з метою формування їх будівельних властивостей шляхом ущільнення вапняними палями. Наведені позитивні приклади застосування вапняних паль, описані технологічні прийоми на етапах виконання робіт, а також механізм формування зміцненого палями ґрунту. Наведені характерні особливості карбонатної сировини, з якої виготовляють повітряне вапно та його якісний діапазон для виготовлення паль. Кінцеві результати дозволяють забезпечити надійну експлуатацію основ під насипами автодоріг.

Ключові слова: вапняні палі, водонасичені глинисті ґрунти, основи насипів.

ИЗ ОПЫТА ПОДГОТОВКИ ОСНОВАНИЙ ПОД ГРУНТОВЫЕ НАСЫПИ АВТОДОРОГ И ЗДАНИЙ С УСТРОЙСТВОМ ИЗВЕСТКОВЫХ СВАЙ

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Аннотация. Рассмотрены способы и технологические особенности подготовки оснований из слабых водонасыщенных глинистых грунтов с целью формирования их строительных свойств путем уплотнения известковыми сваями. Приведены положительные примеры применения известковых свай, описаны технологические приемы на этапах производства работ, а также механизм формирования упрочненного сваями грунта. Приведены характерные особенности карбонатного сырья, из которого изготавливают воздушную известь и ее качественный диапазон для изготовления свай. Конечные результаты позволяют обеспечивать надежную эксплуатацию оснований под насыпями автодорог.

Ключевые слова: известковые сваи, водонасыщенные глинистые грунты, основания насыпей.

Introduction (problem statement). From the practice of construction, lime is known to be applied for improving the building properties of weak water-saturated clay and clogged soils and use them as bases [1].

Analysis of recent research and publications. The first information of lime use in the preparation of soil bases is known in China in the past century [1]. At the beginning of the last century, short lime piles arranged for warehouse pack-houses at the station Kiev-Commodity. In the 60s of the last century, this type of piles was successfully applied on the motorways Odessa-Kyiv village Altestov Odessa region. At the present stage [2-4] accumulated sufficient experience of using lime for the installation of limestone piles. So Abelev M. Y. [4] presents a large-scale positive experience in the introduction of limestone piles (75 – 77% activity) in forest high-plastic loams in the construction of a workshop of a motor plant in the Altai. Reducing the coefficient of soil water saturation S_r to 0.7 allowed further consolidating of heavy ramps basis. At the same time, the value of the average density of the dry soil was more than 1.6 g/cm^3, and within the compacted layer varied from 1.6 to 1.88 g/cm^3. On this basis, basements with a medium pressure of 0.25 MPa were made. The average settlement of the manufactory after 11 years of operation was 14.3 cm. Also, the results of laboratory tests [5] showed that soil moisture after the laying of limestone piles is reduced by 8%.

The purpose and goal of the research are to identify the qualitative parameters of the lime, which is used for the piles, starting with the characteristics of the derivative component for the annealing of raw materials. The raw materials for the production of lime are carbonate rocks: chalk, limestone, calcareous clay, and others. For the production of lime, solid rock with a strict limit of compression of more than 60 MPa is used; medium hardness 30 – 60 MPa; soft 10 – 30 MPa; very soft < 10 MPa, with a fractional proportion of 5 – 20, 20 – 40, 40 – 80, 80 – 120, and also soft without fractionation.

From the experience of implementation. When mass production is on an industrial scale, air lime with an activity of ≈ 80% is obtained. Taking into account its characteristics, air-calcium (predominantly) and air-magnesian (partially), which is reflected in the table 1, are the most suitable for the manufacture of limestone piles.

Depending on the ratio of calcium oxide and magnesium content, the lime is divided into calcium, magnesium and dolomite. Lime has a different dispersion. Lumpy quicklime is called lime. In the technological cycle of rocketing carbonate rocks a significant part of the dust-like components is appeared. To ensure the maximum yield of lumpy lime it is briquetted on special equipment (roll press of the Institute of Ferrous Metallurgy of the National Academy of Sciences). The technical requirements for air lime in accordance with [6] are presented in Table. 2

Table 1 – Technical requirements for the composition put forward to air lime

Composition	Classes of carbonate rocks (Ost 21-27-76)					
	A	B	C	D	E	F
– calcium carbonate *$CaCO_3$*, % not less than	92	86	77	72	52	47
– carbon monoxide *$MgCO_3$*, % not more	5	6	20	20	45	45
– clay impurities $SiO_2 + Al_2O_3 + Fe_2O_3$, % no more than	3	8	3	8	3	8
– grade of the received lime (GOST 9179-77)	air-calcium		air-magnesian		air-dolomite	
	the first, the second	the second, the third	the first, the second	the second, the third	the first, the second	the second, the third

Table 2 – Technical requirements for air lime, % by mass and grade

Component	Unslaked lime,% by weight and grade					
	calcium			magnesian and dolomite		
	the first	the second	the third	the first	the second	the third
Active CaO_4 + MgO, not less than						
– without additives	90	80	70	85	75	65
– with additives	65	55	–	60	50	–
Active MgO, not more:	5	5	5	20 (90)	20 (40)	20 (40)
– without additives	3	5	7	5	8	11
– with additives	4	6	–	6	9	–
The grain is not slaked not more than	7	11	14	10	15	20
Note: the brackets contain the content of MgO in dolomite lime in%.						

Depending on the time quicklime is divided into: fast-slaked (up to 8 minutes), medium-slaked (up to 25 minutes) and slow-slaked (over 25 minutes).

The raw material for roasting is fractionated in size, on average 40 – 180 mm [6]. All types of lime have a crystalline structure, but the size of the crystals and the distance between them vary widely. Pure calcium and magnesium oxides crystallize in the cubic system. The porosity of lime is between 18 and 48% (on average 35%). The density of lumpy lime is 1.6 – 2.5 t/m^3, the bulk density is 0.8 – 1.0 t /m^3, scratch resistance on Mohs scale is 2 – 3.

Theoretically, the specific consumption of rock mass in the production of lime from calcareous clay and limestone shell is 1.75 – 1.9 t/ton of lime. In practice, carbonation of carbonates in lime during firing does not proceed completely, a small part of CO_2 remains. The process of carbonization of lime reaches a maximum at 700 ° C for dolomite and 900 ° C for calcite. There are inclusions SiO_2, Al_2O_3, Fe_2O_3 in the raw material, which have a catalytic effect on the firing process, which reduces the theoretical temperature of decarbonization.

The above information allows to choose the proportion of air lime for the installation of limestone piles.

The results of research. The limestone piles are used with densified weak water-saturated clay soils. The diameter of the wells for the arrangement of piles ranges from 300 to 500 mm. In most cases, they are satisfied with casing pipes, which maintains the vertical and integrity of wells walls. Wells are harassed in quantities of 4 – 5 units. Prepared wells are filled with unpolluted lime at a height of not less than 1,0 m. The laid portion of lime is sealed with a ramp of mass 300 – 400 kg. Recently, the most effective is the use of hinged hydraulic hammer mills, hydraulic ramps and other hydraulic impacts, which can significantly reduce the time of lime sealing in wells. As the lime is sealed, the casing pipes are raised from the wells and so until the end of the trampling process, thus the soil undergoes multiple sealing. At the initial stage, it is sealed when immersed in a casing, and then gradually, when lumbering is done. As a result of the initial trampling, the diameter of the pile is increased by 30 ... 40%. When interacting with porous water, unslaked lime is extinguished. At the end of quenching, the volume of lime is increased to 3 – 4 times, and the diameter of the limestone powder increases by 60 ... 80%. The total increase in volume (due to trampling and extinguishing) is up to 1.6 – 2.0 times. The quenching rate and the final parameters of increasing the volume of the limestone dust affect the initial characteristics of the soil, which is also compacted and the quality of unslaked lime. For the manufacture of limestone piles it is necessary to apply lime with an activity of not less than 75% [3]. For analysis given data in tabl. 1.

As noted in [2], when extinguishing unslaked lime CaO and formation in the quenching of slaked lime $Ca(OH)_2$ in the trunk of the lime pile and in the surrounding contact volume of the strengthened soil, the following processes occur:

– saturation of the surrounding soil with colloidly divided soil containing calcium oxide;

– sealing and crystallization of calcium oxide hydrate with the formation of rigid structural bonds between soil particles and aggregates;

– absorption of finely divided colloidal part of the soil of calcium ions and rolling into strong units;

– partial carbonization of calcium oxide hydrate with the formation of rigid structural bonds with lime carbonate (calcite);

– formation of calcium silicates in the interaction of calcium oxide hydrates with moving carbon dioxide forms.

When added to the water-saturated soils of unslaked lime (when extinguished) there is an exothermic reaction with the release of heat: $CaO + H_2O_R + 155$ kcal. Hydrate of calcium oxide is released in a finely divided state. When extinguishing 1 kg of lime is released on average 277 kcal, and the volume of the limy body is increased in 2 – 3.5 times. When added to such a ground of calcium chloride, compounds of the Sorrel cement type $n\ CaO\ CaCl_2\ 6H_2O$ are formed, which increases its strength.

According to Abelev M. Y. [4], under the influence of pressure in the process of increasing the volume of the pile during extinction around the limestone piles there is a pore pressure. At the same time, the porous water is pressed into the crayfish, that is, its large amount is lost and the humidity of the surrounding soil decreases. As a result of the processes occurring during the formation of limestone piles, the strength and deformation characteristics of around the field weak soil are improved.

Shvetsov I. [3] notes that when changing the coefficient of water saturation S_r of the soil to values of 0.7 and below, the soil can be densified with heavy ramps.

From the practical experience, a layer of locally ground soil thickness of 1.5 – 3.0 m thick and thickened with heavy ramps or sloping with a layer filler is offered over a layer of impregnated clay soil compacted with limestone piles.

Analyzing the state of the raw material base of the Odessa region – the availability of a large stock of cheap limestone-shellfish, mined in quarries and galleries, is an opportunity to create industrial capacities for the production of large volumes of unslaked lime and to use it when arranging artificial bases on weak clay soils. Below are the data from the report [7], see tabl. 3.

From Table 3 it is evident that the most qualitative characteristics of the Kodyma factory of building materials. In order to increase the characteristics of other industries, additional enrichment is required with a decrease in the content of the admixture.

Table 3 – Data on construction lime of the Odessa region on August 15, 1988 (average value)

	O_2	Al_2O_3	Fe_2O_3	CaO	MgO	related impurities
Orlovsky Building Materials Plant						
average value	9,52	1,72	0,9	47,34	0,70	36,6
Kodyma Factory of Building Materials						
average value	0,31	0,41	0,12	91,7	2,09	0,22
Odessa Mine Office						
average value	8,02	1,10	1,30	47,35	1,03	38,87
Glavansk Plant of Building Materials						
average value	27,5	0,92	0,99	37,96	3,95	29,69

Conclusions and perspectives of further research:

1. The accumulated practical experience and experimental researches allow at the present stage to apply a way of improving the building properties of weak soils by means of their consolidation with limestone piles.
2. Implementation of the method of fixing the soil with limestone piles for specific soil conditions should be tested on the basis of the experiment with subsequent use at the design and construction stages.
3. The information in the article allows to construct the course of research in the presented direction with the feasibility study on the choice of the raw material base.
4. It should be noted that the introduction of some reagents increases the strength of the beside aea soil, and should also be justified by additional research data.
5. Extraction of local raw material (shell rock) of the Odessa region allows it to be widely used for volume production of air lime, which is then used to improve the building properties of weak soils as the bases for roads and in mass construction.
6. Accordingly, in Table 1, the cheapest lime is of the 2nd and 3rd varieties, which in general affects the cost of construction work.

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