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ВПЛИВ ДРІБНИХ ЗАПОВНЮВАЧІВ НА ХАРАКТЕРИСТИКИ ВІБРОПРЕСОВАНОГО БЕТОНУ НА ОСНОВІ НАДЖОРСТКИХ СУМІШЕЙ

THE INFLUENCE OF FINE AGGREGATES ON THE CHARACTERISTICS OF VIBRO-COMPRESSED CONCRETE BASED ON ULTRA-HARD MIXTURES

Лічнов І.С., аспірант, ORCID 0009-0004-7924-4274 (Національний університет Львівська політехніка м. Львів)

Lichnov I., postgraduate student, ORCID 0009-0004-7924-4274 (National University Lviv Polytechnic, Lviv)

Публікація висвітлює проблеми фізико-механічних та фізико-хімічних властивостей інертних заповнювачів та зв'язного вібропресованих фігурних елементів мостіння, які виготовляються на сучасних високотехнологічних бетоноформувальних комплексах.

The publication highlights the problems of physical-mechanical and physical-chemical properties of inert aggregates and cohesive vibro-pressed shaped paving elements, which are manufactured on modern blockmaking machines of leading German machine-building manufacturers based on fine-grained ultra-hard and hard concrete mixtures in the latest conditions of development of the construction industry in Ukraine. An analysis of factors affecting the operation of concrete paving stones and causing increased requirements for their physical-mechanical properties has been conducted. In this article, the author studies the granulometric composition, sieving curves, chemical composition, X-ray phase analysis of the product of grinding strong rocks, washed construction sand with gradation factor more than 2.1 and the chemical composition of Portland cement CEM 42.5 produced by "Ivano-Frankivskcement", which are used in the production conditions of the Trade Mark "Mii Dvir" for the production of fine-grained concrete mixtures using specialized dosing and mixing equipment in the process of serial production of figured paving elements. The article determines the main factors that form the strength characteristics and durability of concrete at the early and late stages of its hardening; considers the factors that create conditions for factory vibropressing of products of this category and provides components that should be considered optimal for creating highly efficient ultra-hard concrete mixtures. The materials of the publication present experimental data on the content of the main components of concrete in each of the layers of building

products. These studies were conducted in the scientific laboratory of the National University "Lviv Polytechnic" according to domestic and European standards by the method of forming beams measuring 40x40x160.

Keywords: paving stones, ultra-hard concrete mixtures, fine aggregates, characteristics of vibro-compressed concrete, concrete blockmaking machine, compressive strength.

Introduction. The issue of developing technologies for industrial vibro-pressing of concrete paving stones with high architectural expressiveness and increased operational characteristics is relevant. A whole series of scientific studies determines that among the most effective technological techniques to produce high-quality concrete paving stones is the method of vibro-pressing hard and ultra-hard concrete fine-grained mixtures. This served as the basis for the creation of highly productive production complexes in developed foreign countries (USA, Germany, Great Britain, etc.). It is necessary to note the significant scientific research of scientists from Germany in the direction of cement technology [1], the basic principles of production and the use of small aggregates, such as sand and crushed stone [2, 3].

The properties of aggregates, the principles of structure formation, the influence of the form of aggregates on the properties of concrete are considered in detail. The work of Kuch, H., Schwabe, J.H., and Palzer, U. examines the production of concrete products using modern equipment and provides detailed explanations of the materials used in production, as well as described technological and examples existing schemes of the production process [4]. Research on the modelling of the optimal dimensions of concrete pavers for docking in the process of road surface construction was carried out by specialists [5].

The trends in the implementation of the latest technologies of vibro-pressing of fine-grained concrete based on ultra-hard and hard mixtures, as well as the peculiarities of industrial production and the aggregates base for vibro-compressed concrete are considered in the works [6, 7]. Despite the entire complex of previously conducted scientific research on the properties of vibro-pressed concrete, to this day there remain several problematic issues related to the physical-chemical and physical-mechanical properties of the components of fine-grained ultra-hard mixtures and the nature of the formation of a dense structure of the top layer of paving stones on the technological blockmaking machines of the new generation.

The main tasks of solving the above should include the analysis of the study of the problems of the factory production of paving stones from coloured ultra-hard fine-grained concrete on modern concrete forming equipment and the establishment of factors that determine the characteristics of the components used. At the same time, the effect of small aggregates on the formation of a dense cementing matrix of fine-grained concrete should be highlighted.

The study of the production processes of paving elements from coloured ultra-hard fine-grained concrete on modern concrete-forming equipment and the establishment of factors that shape the prospects for determining the optimization of the used components is important for solving the above-mentioned problems. At the same time, the problem of the effect of small aggregates on the formation of a dense structure of vibro-pressed concrete is particularly relevant.

The most important characteristics of concrete pavers for bridges and other concrete products made of vibro-pressed fine-grained concrete are:

- high compressive and splitting strength, as well as correspondingly high bearing capacity of concrete;
- high resistance to frost and the influence of anti-icing agents;
- low abrasion;
- high resistance to chemical corrosion (due to the influence of aggressive rain and storm water, so-called acid rain and aggressive bases of fats, lubricants, fuel, etc.);
- aesthetics and functionality (many standard sizes, shapes, colours and thickness adapted to the external surface).

What is confirmed by research on the technological properties of concrete paving by authors [8, 9, 10], experts from Australia [11], scientists from Kazakhstan [12].

The indisputable advantages of concrete paving elements based on vibro-pressed concrete include a long service life (at least 50 years), a low price compared to reinforced concrete paving slabs, asphalt pavement, cast concrete and natural stone, the possibility of dismantling the previously installed pavement and its reuse, as well as the convenience of maintaining the cleanliness of sidewalks and road surfaces in cities and settlements of different countries of the world, confirmed by the studies of researchers from all continents of the world [13, 14, 15, 16, 17].

The complex operating conditions of concrete paving stones force the leading manufacturers to use very high-quality raw materials and require appropriate technology, reliable control of the quality of raw materials, the use of modern lines to produce concrete mixtures and the process of concrete compaction; maintenance of forming technological lines in appropriate technical condition.

Due to the extreme conditions of operation of small-sized concrete shaped elements of paving in pavements and road surfaces, concrete paving stones become dependent on the criteria for ensuring the durability of construction products, which are established during technological techniques and processes in the production cycle, as well as when using modern methods of assessing quality and the level of technical requirements, which refer to concrete paving stones.

In the period from 2023 to 2024, on the basis of normative modern research methods of standard tests for construction products according to existing European and domestic regulatory and recommendatory documents, comprehensive studies of the main physical-mechanical and physical-chemical properties of fine

aggregates and other components of concrete mixtures in the manufacture of fine-grained compositions were carried out textured (top, coloured) layer of vibro-pressed shaped paving elements based on hard and ultra-hard mixtures.

Materials and Methods. The purpose of this publication is to single out the main factors that form the increased physical and technical properties of fine-grained vibro-pressed concrete and a dense structure based on ultra-hard concrete mixtures for the industrial process of concrete paving during its mass production and the influence of aggregates on this technological process.

- Cement II/A-S 42.5 R production of Ivano-Frankivskcement.
-Quartz sand Modulus of coarseness >2.1.
- The product of grinding hard rocks (granite).

Determination of the activity of Portland cement DSTU B V. 2.7-187:2009, and the results of the study of the Portland cement brand "Ivano-Frankivskcement" are presented in the table. 1.

Table 1.

Indicators of physical and mechanical properties of various Portland cements in different periods of time

Portland cement	W/C ratio	Cone blur, mm	Bending/compressive strength limit, MPa Age, days			Surface area, m^2/kg	Normal thickness of the cement paste, %	Fineness of grinding, %
			2	7	28			
CEM I 42.5 R	0,39	115	6,8 / 32,6	8,1 / 48,4	8,2 / 57,0	435	30,0	0,4
CEM II/A-S 42.5 R		115	6,5 / 30,2	7,2 / 44,6	8,1 / 54,6	477	30,5	0,8
CEM II/A-S 42.5 R (march)		114	5,9 / 27,0	7,9 / 43,2	8,6 / 54,8	425	30,0	0,0
CEM II/A-S 42.5 R (may)		116	5,8 / 26,6	8,0 / 42,4	8,1 / 55,6	421	30,0	0,4
CEM II/A-S 42.5 R (august)		115	5,9 / 28,0	7,8 / 43,0	8,2 / 56,4	430	30,0	0,4

The results of studies of physical and mechanical properties based on tests of quartz sand with a coarseness modulus >2.1 and the product of grinding granite material are presented in table. 2..

Figures 1 show the results of studies of the strength and deformation properties of the influence of small aggregates (sand from the Slavuta quarry and the product of crushing granite material of the fraction 0.63-2 mm) on the characteristics of fine-grained vibro-compressed concrete, which were carried out by the author in 2023-2024 in laboratories of the Lviv Polytechnic National University.

Table 2.

Physical-mechanical properties of sand gradation factor >2.1 and the product of crushing granite material

Characteristic	Unit of measurement	Indicator value		
		Standard	Actual	
			Sand	Product of crushing granite material
Dry bulk density	kg/m^3	≥1100	1560	1305
Real density	g/cm^3	2,0 – 2,8	2,6	2,6
The presence of grains from 5 to 10 mm	mass %	≤ 10	-	-
The content of grains passing through a sieve № 016	mass %	≤ 15	3,4	2,2
Full balance on the sieve № 063	mass %	≤ 10	40,9	75,7
Gradation factor	-	1,0 – 1,5	2,12	3,05
The content of dust and clay particles	mass %	≤ 1,0 ≤ 3,0	-	-
Voidness	%	< 30 ..> 40	40,0	49,8

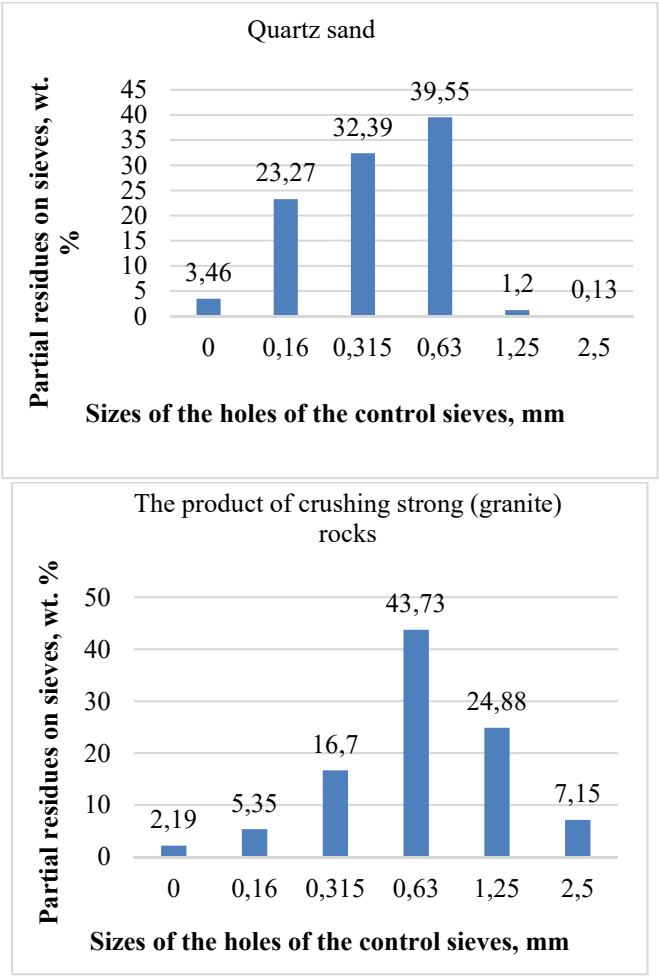

Fig. 1. Dispersion curves (granulometric composition) of construction quartz sand with Gradation factor >2.1 a and the product of grinding strong granite rocks b.

Results and discussion. The results of the selection of vibro-pressed concrete mixtures of the obtained working compositions based on fine aggregates. Used proportions of components and construction materials.

Cement: Sand = 1:3; *1:3,69

CEM II/A-S 42.5 R

DSTU sand; Sand EN Sand Hlibovychi; Slavuta sand; Product of crushing granite material

Form samples 40x40x160 mm.

Table 3.

The results of determining the compressive/flexural strength of cement-sand concrete based on hard (water-cement ratio ≈0.4) mixtures with different compositions of fine aggregates to produce a top layer of vibro-pressed concrete pavers produced by TM "Mii Dvir"

Aggregate, additive	W/C ratio		Cone slump, mm	Bending/compressive strength limit, MPa/kgf (MPa) Age, Days		
				2	7	28
Sand according to DSTU (1:3)	0,39		107	**3,99 /** 4000, 4000 **(16,0)**	**7,36 /** 7400, 8600 **(32,0)**	**7,45 /** 7400, 8600 **(42,6)**
Slavuta sand (1:3)	0,40		109	**2,55 /** 2100, 2300 **(8,8)**	**4,10 /** 4000, 4200 **(16,4)**	**5,97 /** 7600, 7400 **(30,0)**
Product Grinding of hard (granite) rocks (1:3)	0,41		110	**4,13 /** 4600, 4700 **(18,6)**	**7,45 /** 8800, 8200 **(34,0)**	**8,01 /** 11800, 11500 **(46,6)**
Slavuta sand 40% + Product Grinding of hard (granite) rocks 60%	0,41		108	**3,22 /** 3600, 3500 **(14,2)**	**6,21 /** 7500, 8300 **(31,6)**	**9,17 /** 12900, 12000 **(49,8)**

Conclusions. During the last decades, modern Ukraine has joined the global trend of introducing ultra-hard and hard concrete mixtures in the process of vibro-compressing on blockmaking machines to produce concrete paving stones. The world experience of producing concrete paving stones by the method of semi-dry vibro-pressing at the production facilities of TM "Mii Dvir" (Lviv) indicates the need for further thorough scientific research in the field of improving the technology of preparing ultra-hard mixtures from conditioning components and the process of improving the method of vibro-compressing concrete in a closed circuit of metal molds with a punch load of a high-performance concrete forming complex. At the same time, one should consider the significant influence of the quality and particle size composition of fine aggregates for vibro-compressed concrete paving stones.

The studies presented in the publication confirm the significant influence of aggregates on the properties of vibro-compressed concrete based on ultra-hard, and the optimal working compositions proposed by the author are the key to obtaining a dense structure of the investigated mass-produced concrete. The physical-chemical and physical-mechanical characteristics of quartz sand with a gradation factor > 2,1 from the Slava quarry and the products of grinding strong rocks

(granite) clearly testify to the effectiveness of their use under the condition of using Portland cement manufactured by Ivano-Frankivsk cement.

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