

Examination of Quality and Operational Properties of Vibropressed Paving Elements

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Abstract. This article presents research findings on examination of quality of paving elements. Were investigated and analyzed performance properties of paving slabs on following: accuracy of geometric dimensions, appearance, compressive strength, frost resistance, water absorption and abrasion. Based on these results recommendations improving the current regulatory and technical documentation are provided.

1 Introduction

An artificial paving stone is a concrete element with section height (thickness) of not less than 60 mm, bearing surface area of not more than 0.05 sq. m and maximum length of 28 cm and 30 cm, for rectangular and shaped artificial stone, respectively. Paving stones are produced with the thickness of 60, 70, 80 or 100mm. Requirements for artificial paving stones are indicated in the following documents: GOST 17608-91 "Concrete Sidewalk Plates. Specifications", TS 5746-001-33157194-97" Artificial Stones of Road Topping, "TS 5746-018-03984296-2004" Concrete Sidewalk Products "and TS 5746-020-03984296-2005 "Concrete Sidewalk Plates with Textured Surface".

Concrete paving slabs are made of heavy and fine-grained (sandy) concrete, and are used for prefabricated pavements, pedestrian and park paths, pedestrian areas and public transport loading sites.

Therefore high requirements are imposed to the quality of the finished goods.of the artificial stones producers.

According to ISO 9000:2005 (Quality Management Systems — Fundamentals and Vocabulary), quality is a “degree to which a set of inherent characteristics fulfils requirements”. There are various classes of characteristic, such as the following:

- physical (e.g. mechanical, electrical, chemical or biological characteristics);
- sensory (e.g. related to smell, touch, taste, sight, hearing);
- behavioral (e.g. courtesy, honesty, veracity);
- temporal (e.g. punctuality, reliability, availability);
- ergonomic (e.g. physiological characteristic, or related to human safety);
- functional.

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As a rule the physical, the sensory, the temporal and the functional ones are exposed to examination among the listed characteristics above during quality assessment.

In [4] scientist have developed a mathematical model and calculation method, which takes into account the connection between the paving stones in surface coating, their shapes and sizes. The influence of shapes, sizes, artificial stone paving and joints in the coating on the strength of the pavement are experimentally and theoretically investigated.

Developed practical recommendations on the calculation, design, construction and evaluation of the strength of road pavements coated with artificial stone paving. A significant influence of friction forces wedges between the stones has been revealed. A general formula for determining the stiffness of joints has been suggested.

Also A.V. Kochetkov, M.L. Ermakov, A.A. Shestopalov, E.I. Denikin, J.G. Barabanshikov, S.G. Nikolskiy, S. Belyaeva, A. Korsun, V. Korsun, V.D Staroverov [8-21] study the quality assessment elements paving and other building materials.

The aim of this work is to improve the methods and the regulatory guideline of quality control road surface paving elements.

For this control was carried out examination of the quality of paving slabs, consisting of two stages: quality control of products and an experimental analysis of the properties of finished products.

Experimental studies were carried out on the basis of research laboratory of the Department "Examination of Consumer Goods" VPO "SPbGTEU"

2 Monitoring and Examination of Quality of Paving Slabs

To carry out random check of paving slabs were taken 3 lots of paving slabs produced by Experimental Plant JSC:

- Lot No. 1- paving slabs of 1-P-8 "Brick" gray color; the geometrical sizes are 206x102x80 mm (Fig. 1 (a)),
- Lot No. 2 - 1-F-8 "Volna", gray colour. геометрические размеры 225x112x80 mm (Fig. 1 (b)),
- Lot No. 3- paving slabs 5-F-6 "Klassika-Rusto", gray colour геометрические размеры 119x119x60 mm (Fig. 1 (c)).

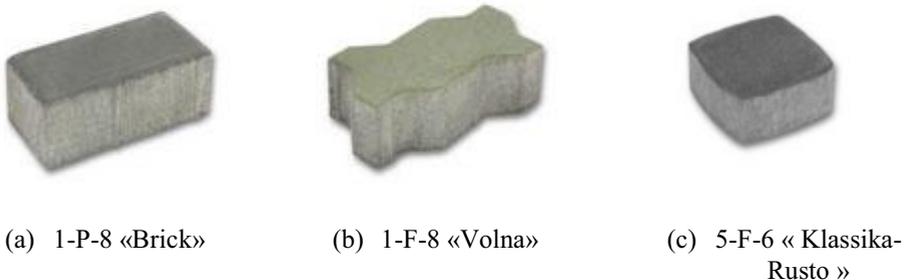


Fig. 1. The models of research

All the researched lots have the declared concrete class for compressive strength B35 and for frost resistance F200

Quality control was performed in accordance with GOST 17608-91 and TS 5746-003-23078401-08.

The size of paving slab lot was 80 units. Sampling was conducted in accordance with the requirements of GOST 17608-91. Five paving slab samples shall be taken from a lot of up to 100 units.

During the quality control inspection we checked the following: if there are transport documents, unhurt package, correct marking; if the products comply with the application form; if there are any defects in appearance; as well as the category of front concrete surface, dimensions, upper layer thickness, straightness of front surface profile, front surface flatness, perpendicularity of front and adjacent faces.

While inspecting transport documentation we checked the following: the certificate of compliance with GOST 17608-91 and TS 5746-003-23078401-08, installation instructions, warranty conditions, a shipping list.

During package checking we inspected package and its condition. Slabs are usually put on reusable pallets. Pallet with the products are wrapped with stretch film to prevent spillage of products during transportation, and fixed with metal, polypropylene, or any other tape, ensuring the safety of stones.

During monitoring marking accuracy we checked its compliance with the requirements of GOST 13015 - 2003 Reinforced Concrete and Concrete Construction Products. General Technical Requirements. Rules of Acceptance,

Marking, Transportation and Storage. Markings and labels are specified on the label attached to the pallet with the products. Marking label shall contain the following marks:

- A trademark of the manufacturer or its short title;
- Product designation;
- Indication of standard;
- A Stamp of QC department;
- Date of product manufacture;
- A number of products on a pallet.

Marking method shall ensure its safety before packing products; it shall be indicated in the technical documentation. In accordance with these requirements the following data in the marking of paving slabs shall be verified: marking shall be affixed indelibly on the end face of at least 10% of plates from a lot. Plates are marked in accordance with GOST 23009 Designs and Products, Concrete and Reinforced Concrete Prefabricated. Sign Designation (Marks).

Marks of square, rectangular, hexagonal, and bordering plates consist of alphanumeric groups which mean the following: the first digit - serial number size; a letter – plate type; a number after the letter - slab thickness in centimeters; which depends on foundation type. Marks of curly plates consist of alphanumeric groups separated by dots, indicating: the first digit - serial number of this configuration; the letter F - type plate; a number after the letter F - serial number plate; the last digit - slab thickness in centimeters.

During appearance control of paving slabs we visually checked if there are any of the following defects: cracks, chips, shells, sagging, uniformity and color intensity.

The category of front concrete surface is A6, the category of non-front surface - A7 according to GOST 13015 -2003 Reinforced Concrete and Concrete Construction Products. General Technical Requirements. Rules of Acceptance, Marking, Transportation and Storage.

Inspection of dimensions for compliance with GOST 17608-91 was performed using measuring tools, in particular calipers.

The thickness of the upper layer of paving slabs was tested with the help of calipers for compliance with the requirements of TU 5746-003-23078401-08

Deviations in straightness of front surface profile was checked with plumbing metal squares.

Deviations in front surface plane and in perpendicularity of end and adjacent faces were also checked with plumbing metal squares.

3 The Results of Quality Control Sampling of Paving Slabs

During quality control sampling we revealed the following:

1. Each lot has a compliance certificate, instructions for paving slab installation, warranty conditions, transport list; which meets the requirements;
2. Package of each paving slab lot is not damaged;
3. All samples of paving slabs are marked in accordance with GOST 17608-91, the product brand is also indicated.
4. While evaluating appearance of paving slab samples of the brands 1-P-8, 1-F-8 and 5-F-6 it was revealed that the samples of all three lots have no defects in appearance; which meets the requirements;
5. The dimensions of paving slab samples of 5-F-6 brand have no deviations in length, width and thickness.
6. The dimensions of paving slab samples of 1-F-8 brand have length deviation of +1mm in one sample; width deviation of + 2mm and + 1mm; thickness deviation of + 1mm and -1mm.
7. Upper layer thickness of all samples in three lots complies with documentation requirements equaling to more than 10 mm.
8. There is no deviation in straightness of front surface profile in all samples of three lot.
9. Deviation in the plane of the front surface of one sample of 1-P-8 brand is 1 mm, the same deviation occurs in one sample of 5-F-6 brand. There are no deviations in samples from 1-F-8 brand.
10. There is no deviation in perpendicularity of end and adjacent faces in all the samples from three lots.
11. Samples from all three lots comply with a standard of reference.
12. The category of the front surface of samples from all three lots complies with A6.
13. All samples have no surface cracks on stones from all three lots.

Based on the abovementioned facts, we can conclude that the paving slabs produced at Experimental Plant JSC of the brands 1-P-8, 1-F-8 and 5-F-6 have only minor deviations in analyzed parameters and fully comply with all the requirements of GOST 17608-91.

4 The Examination of Operational Properties of Paving Slabs. Examination Subjects and Methods

For examination of paving slabs produced at Experimental Plant JSC, fourteen brands of paving slabs were taken: 1-P-8, 1-F-8, 1-F-6, 2-F-8, 3-F-8, 1-P-6, 4-P-6, 7-P-8, 9-F-8, 5-F-8, 6-F-6, 7-F-6, 8-F-6, 2-P-6. These brands are the most common and produced in the largest amount in Experimental Plant JSC.

During tests, up to 0.1% of the total amount of paving slabs is subject to inspection. In order to do this, the cubes with an edge length of 70 mm are cut. Deviation in straightness of bearing surfaces must not exceed 0.1 mm. It is necessary to test compressive strength, flexural strength, abrasion resistance, frost resistance, water absorption, water permeability.

Determination of concrete strength consists of measuring the minimal effort, destroying specially prepared test concrete samples during static loading at a constant rate of load growth and the subsequent calculation of stresses in these efforts, assuming elastic behavior of the material.

The methods and test procedures are described in GOST 10180-90 Concrete. Methods of Determining Strength by Control Samples, GOST 13087-81 Concrete. Methods of Determination of Attrition, GOST 10060.0-95 Concrete. Methods of Frost Resistance Determination.

During testing of compressive strength the control samples are put on a support plate of a hydraulic press and gradually loaded with the upper baseplate until fracture. A study of three test samples is presented.

During tensile flexural test the samples are put on two supports. The force is transmitted by a round steel bar of 10 mm in radius, installed in the middle of a slab parallel to the supports.

In order to determine the friability the control samples or parts of slabs obtained after their bending test are used. Tests are carried out using a special abrasion abrasive wheel with a rotational speed of 30 rev / min. It makes 110 turnovers. After this it is necessary to calculate amount (mass) loss of the sample with the abraded surface of 50 cm².

Determination of frost resistance of concrete is performed on three control samples with the help of the second reference method. Frost resistance is the ability of concrete to maintain the physical and mechanical properties after repeated freezing and thawing. All samples were previously saturated with 5% aqueous sodium chloride solution and undergo 30 cycles of freezing (at -18 ° C) and thawing (at +18 ° C); there shall be no cracks and flaking external surfaces.

Water absorption is determined by the difference in product weight. A product shall be completely dried within several hours at a high temperature. The dry product weight is measured; then it is soaked for several hours. Then it is necessary to calculate the weight difference between wet and dry products. After that one shall calculate the percentage of water in the product.

5 The Results of Examination of Operational Properties of Paving Slabs

Analysis of the experimental data for paving slabs (1-P-8, 1-F-8, 1-F-6, 2-F-8, 3-F-8, 1-P-6, 4-P-6, 7-P-8, 9-F-8, 5-F-8, 6-F-6, 7-F-6, 8-F-6, 2-P-6 brands.) revealed that:

1. The strength limit of concrete for compressive strength varies from an average of 50.01 MPa to 51.9 MPa. All samples were analyzed by compressive strength exceed the requirements of GOST.

2. The value of handling concrete strength varies from 49.5 MPa to 50.8 MPa, 1-F-8 brand has the best results. For this indicator, paving slabs, manufactured at Experimental Plant also JSC exceeds the requirements of GOST.

3. The strength limit of concrete for tensile strength in bending all kinds of paving slabs is 6.8 MPa, which is higher than the requirements of GOST.

Thus after analyzing combined indicators of concrete strength for paving slabs produced at Experimental Plant JSC we can conclude that these products are of high quality in terms of strength and in all cases the deviation from GOST requirements is positive.

- Frost resistance analysis of experimental data for fourteen types of paving slabs shows the exact compliance with the requirements of GOST 10060.0-95 and equals to F200.

- As for water absorption all brands of paving slabs show results that are better than requirements of GOST 12730.3-78. Concrete. Methods of Water Absorption Determination.

- The average value of abrasion performance for all samples of analyzed paving slabs is 0.39 g/cm². In terms of abrasion the paving slabs of Experimental Plant JSC have the best performance characteristics.

- As for service life of paving slabs produced at Experimental Plant JSC, the average repair of road pavements, pedestrian areas and areas of artificial roads paving stones manufactured at Experimental Plant JSC, which are not designed for the constant traffic of vehicles, shall be implemented after 9 years, major repairs after 24 years. This conclusion is based on analysis of repair periods of cement concrete and small sized pavements.

In order to confirm these repair terms we can mention the fact that some sections of the road surface of the pedestrian zone in Malaya Sadovaya Street (date of commissioning is 1998) made of artificial paving slabs produced at Experimental Plant JSC were repaired in 2007.

Thus, analyzing all the performance characteristics and service life of paving elements produced in at Experimental Plant JSC, we can conclude that the products meet the requirements of GOST 17608-91 and allow to create a strong road surface which maintains its continuity and smoothness under the influence of vehicle traffic and weather and climate factors. Evenness of pavement is a qualitative condition of the coating characterized by the absence of defects: cracks, crevices, ledges, shifts, waves, high joints

6 The Comparative Examination of Adhesion Properties of Paving Slabs with the Different Surface Textures

We conducted a comparative examination of adhesion properties of paving slabs of the type "brick", the brand 1-P-8 manufactured at Experimental Plant JSC with a smooth and relief textured front surface.

The front surface of paving slabs can be smooth or textured (relief). In the first option the face layer is made of only a mixture of sand and cement, and in the second - with inclusion of a filler. Due to adding various solid natural aggregates to the textured front layer of paving stones they have better mechanical strength and decorative properties if compared with stones with the smooth upper surface. There are requirements to face category for the quality of the smooth front surface that corresponds to the limiting values of the diameter or size of the shells, the height of the local influx (projection) or the depth of the depression, a depth of about ribs. The quality of textured surface shall comply with a standard of reference (in the form of a surface of a product fragment) which is approved by the company (GOST 13015-2003 Reinforced Concrete and Concrete Construction Products). The front surface of the stone paving provides a comfortable pedestrian traffic on the road surface, that is, has some traction with the soles of shoes pedestrians. In autumn and winter the front surface of the stone under the influence of moisture and rainfall becomes more slippery and traumatic.

7 The Results of the Comparative Examination

Five samples of the paving slabs of the brand 1-P-8 with textured and smooth surfaces were selected for the comparative examination of adhesion properties of paving slabs

To estimate the coupling properties of artificial stone paving can serve as friction coefficient.

The friction coefficient characterizes the ability of coverage to resist to sliding of car tires and represents the relation of maximum reactive force resisting to longitudinal displacement of the stopped wheel to vertical force (coupling weight) acting through the wheel on the coverage and applying perpendicular to its surface

The friction coefficient of front surface paving stones with shoes of pedestrians was determined with the device DM-T intending for measuring of the friction coefficient of wheel tire with the material of road surface.

Thus the road surface material is the part of the measuring device. Therefore the device allows to measure the friction coefficient in static conditions

The results of comparative examination of paving slabs of the type "brick" of the brand 1-P-8 with different surface textures, produced at Experimental Plant JSC are represented in Table 1.

Table 1. The Results of Determination of Adhesion Coefficient

№	Product Brand	Indicators to be Measured	Requirements STD	Actual values				
				Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1	1-P-8 with a smooth surface	Adhesion coefficient	no	0.51	0.48	0.49	0.49	0.50
2	1-P-8 with a textured surface	Adhesion coefficient	no	0.56	0.57	0.57	0.57	0.56

Analysis of the experimental data leads to the conclusion that the adhesion coefficient of the slabs with textured surface on the average by 0.07 higher. Thus, we can conclude that the performance characteristics of paving slabs with textured surface are the best in the autumn-winter season when it is necessary to provide the most adhere to the road with a shoe pedestrian.

Existing regulations do not reflect the requirements of the operational characteristics, in spite of its importance for the consumer. Therefore, it seems appropriate, the inclusion of the friction coefficient as a measure of quality regulations.

8 Summary

The paving slabs of Experimental Plant JSC are made with the equipment of the last generation of the German company MASA with the method of moist vibropressing. The high level of product quality is ensured by high-tech equipment, high-quality raw materials and professional staff.

On the basis of conducted research and data quality examination of paving slabs we can make the following conclusion:

- The paving slabs of all fourteen brands produced at Experimental Plant JSC for basic operational significantly exceeds the requirements of GOST 17608-91, resulting in a reliable, durable and practical material for durable, aesthetic, easily repaired pavement.
- Comparative examination of the “Brick” type paving slabs of the brand 1-P-8 with textured and smooth surfaces show that the paving stones have the highest performance with relief (textured) surface. It is preferably to use them for pedestrian areas with heavy traffic on the road sections and areas with a significant slope.
- It seems reasonable to include the adhesion coefficient as a quality indicator to regulation documents.

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