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STUDIES OF COATINGS FROM FIGURED OF THE ELEMENTS OF PAVING (FEP) WITH CORRUGATED BASE FROM TOOTHED ELEMENTS OF PYRAMIDAL SHAPE ON THE HORIZONTAL AND INCLINED SURFACES

The new constructive-technological solutions of coatings from FEP (figured of the elements of paving) with the modified geometric by shape of the base were developed. Base FEP consisted of one, five or nine toothed of the elements of pyramidal shape was corrugated. The plan of the experiment and conducted laboratory studies on the effect geometric form of the base of a single FEP on the qualitative characteristics of coatings, located on the horizontal and inclined surfaces under the influence of a longitudinally applied load, was compiled. The experiment results analysis showed that the coatings from FEP with five and nine of the toothed elements in the base prevents the shift more effectively than the traditional coatings.

***Keywords**: figured element of paving – FEP, coatings, a pyramidal shape, a longitudinal shift.*

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ДОСЛІДЖЕННЯ ПОКРИТТІВ ІЗ ФІГУРНИХ ЕЛЕМЕНТІВ МОСТІННЯ (ФЕМ) З РИФЛЕНОЮ ОСНОВОЮ ІЗ ЗУБЧАСТИХ ЕЛЕМЕНТІВ ПІРАМІДАЛЬНОЇ ФОРМИ НА ГОРИЗОНТАЛЬНИХ І ПОХИЛИХ ПОВЕРХНЯХ

Розроблено нові конструктивно-технологічні рішення покриттів з фігурних елементів мостіння (ФЕМ) зі зміненою геометричною формою основи. Зясовано, що рифлена основа таких ФЕМ складається з одного, п'яти або дев'яти зубчастих елементів пірамідальної форми. Складено план експерименту та проведено лабораторні дослідження щодо впливу геометричної форми основи одиночного ФЕМ на якісні характеристики покриттів, розташованих на горизонтальних та похилих поверхнях під дією поздовжньо прикладеного навантаження. Проаналізовано результати експерименту показав, що покриття з ФЕМ з п'ятьма й дев'ятьма зубчастими елементами в основі найефективніше перешкоджають зсуву, ніж традиційні покриття.

***Ключові слова**: фігурний елемент мостіння (ФЕМ), покриття, пірамідальна форма, поздовжній зсув.*

Introduction. The unit of the coatings of the sidewalks, paths, areas for various purposes from figured paving elements has become actual recently [1 – 4]. Due to the fact that such coatings are environmentally cleaner comparativly to asphalt coating and are aesthetically attractive. Due to the gaps between the tiles provided by the outflow of the water from the surface during roll of the rainfall, their service life is prolonged. Such coatings, if necessary, can be easily dismantled, for example, for lying of the underground communications, or easily be replaced with individual deformation of elements. However, in the course of their operation, sometimes some defects can be observed, including loosening and cracking in the individual elements, potholes and dips in the coatings. Such violations occur due to incorrectly selected structural-technological solutions, non-compliance with the rules of operation and the coating unit technology. The problem solution is development of new variants of coating design from FEP with the modified geometric parameters [5].

Analysis of recent research sources and publications. The FEP applied to the unit coatings has different sizes and shapes [6-10]. Their base is commony flat. In the published work [11] constructive-technological-solution of coating from FEP with a pyramidal base (Fig. 1) are proposed. To exclude the cost of concrete for base, volumes should be equal for the FEP with a pyramidal and a flat by base, when they are the same size and shape in plan. This is achieved by reducing the height of the prismatic part of FEP with a pyramidal base. Such coatings are tested in laboratory and field conditions, and was performed a comparative analysis of the research results [12]. Determined, that the coverage of the FEP with by pyramidal base have several advantages compared to traditional coatings.

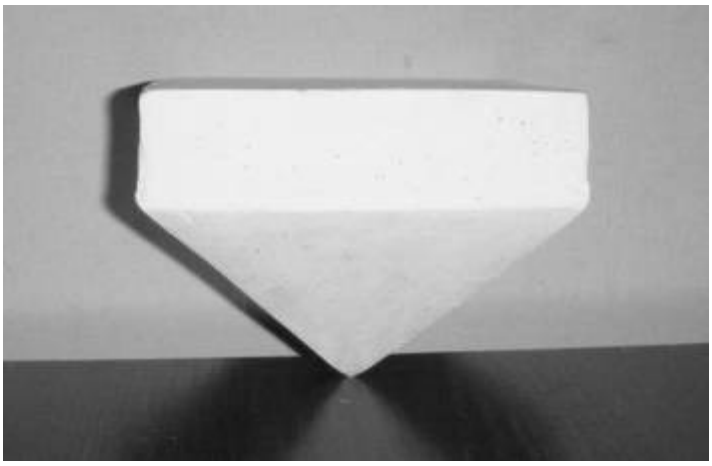

Figure 1 – Model of FEP with a pyramidal base with an angle at the vertex of the pyramid 90^0, made of gypsum

Sediment single element is reduced by half from FEP with the angle at the vertex of the pyramid 70^0 and 1,3 times the FEP with the angle at the vertex of the pyramid 125^0 compared to FEP with a flat base (180^0 at the top of the pyramid). Determined, that the bearing capacity of coating is increases by reducing the angle at the vertex of the pyramid. The study of deformation zones of the constructive sand layer [13] has demonstrated the feasibility of using the developed technological solutions of coatings from FEP with a pyramidal base.

Selection of the unsolved parts of problem. The disadvantage of coating from FEP with a pyramidal base is the complexity of the unit the elements with an acute angle at the vertex of the pyramid. If we take the traditional tile square shape in plan with a side of 120 mm and a height of a prismatic part 50 mm, the height of the prismatic part of the tiles with a pyramidal base with an angle at the vertex of the pyramid 90^0 is equal to 30 mm for the same size and shape in the plan. With a significant reduction of the height of the prismatic

part of the tiles with by pyramidal base, her contour part in contrast to the central part is becomes more vulnerable. The impact of a large load on a contour part can lead to the destruction of the edges of such tiles.

For solving problems, related to improving the bearing capacity of the coatings and to simplicity its of the unit, were developed new variants of coatings from FEP, having the corrugated base from the toothed elements of pyramidal shape [5]. The study of the qualitative characteristics of such coatings on horizontal and inclined surfaces was not performed, therefore it is highly relevant is the conduct of such studies.

The purpose of work – to study the impact of the modified geometric shape of the FEP on a shear of the coatings, located on the horizontal and inclined surfaces, when exposed to the longitudinal load, and the determination of the optimal of options of the coatings.

The main material and results. A new constructive-technological solution of coating from the FEP with a corrugated base from the toothed elements of a pyramidal shape is developed. In this case the FEP should have the shape of a regular polygon in plan. The three options such FEP square shape in plan are offered. In the first option the base of the tile comprises nine of toothed elements of pyramidal shape (the three pyramidal elements, located in three rows). In Fig. 2 this is the first sample on the left.

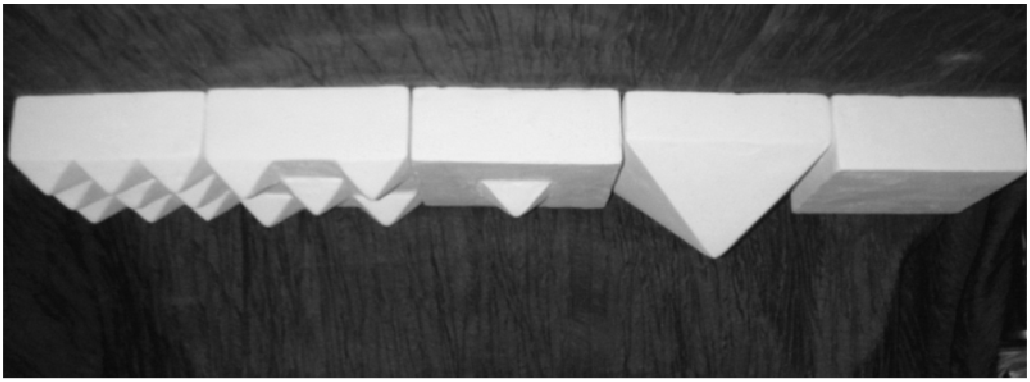

Figure 2 – Samples of the FEP from gypsum, square shape in plan with a side of a square is 120 mm, with different geometric shape of the base and height of the prismatic part

In the second embodiment, the corrugated base is composed of five toothed elements of pyramidal shape (one located at the center and the other four at the corners of the tile). In Fig. 2 is the second sample from the left. The third embodiment – is tile with one toothed element of pyramidal shape, positioned centrally. In Fig. 2 is the central sample. The fourth sample on the left has the base a pyramidal shape with the angle at the vertex of the pyramid 90^0, and the fifth on the left, with a flat base. In our opinion a constructive solution, which was developed, has several advantages. One of them is providing hard pinched of pyramidal elements of each FEP of the coating in the underlying structural layer, therefore, its displacement will tend to minimum. By changing the geometric shape of base of the FEP is receive an additional seal of the underlying layer under the tile. An increase of the area of bearing the base of the FEP on the underlying structural layer leads to transfer the load across larger volume of the structural layer.It leads to the increase of the bearing capacity of the coating from the FEP with corrugated base.

To determine the qualitative characteristics of the proposed coverage from the FEP plan and methodology for conducting the experiment were developed, the materials and equipment were selected. The purpose of the experiment - to determine the value of the longitudinal load applied to the sample, considering longitudinal shift of the sample on 1 mm on the horizontal and inclined surfaces. Parameter longitudinal load acting on the sample with shift gives us the

opportunity to evaluate the work of the coating of tiles with various geometric shape of the base. The tile having the greatest option of the load for fixed shear 1 mm has a greater shear resistance. Coverage of such tiles is committed to maintain its original position.

In order not to get increasing of material costs for toothed elements, it is necessary to reduce the height of the prismatic part of the tiles, so that the volumes of all specimens were equal. By prototype traditional tile of square shape in plan is selected with a side of a square 120 mm and 50 mm high. For test specimens with the same configuration in plan with the angle at the vertex pyramids 90^0 the height of the prismatic part was as follows: the FEP with nine of toothed elements 43,3 mm; with five of toothed elements 46,3 mm; with by one toothed element is 49,3 mm. It should be noted, that reducing of the height of the prismatic part of the FEP with corrugated base slightly compared by height of the prismatic part of traditional tile. However, the difference between the height of the prismatic part of the FEP with a pyramidal base and a traditional FEP with a flat base (with a similar size in plan) is about 20 mm.

Pilot-plant stand was made of metal pan with sandy structural layer (its thickness is 160 mm (Fig. 3).

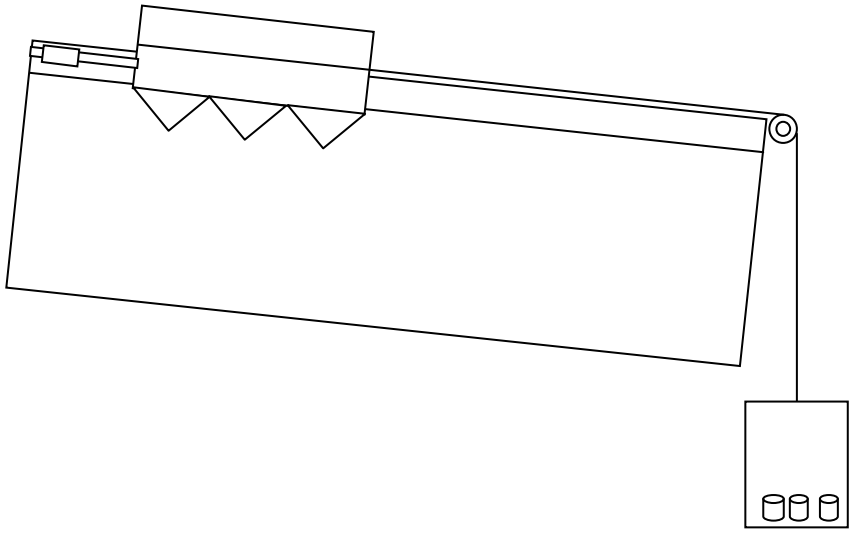

Figure 3 – Scheme of experimental-production bench

The block is installed in the right top side of the tray from the outside. End-to-end to the left end of the tray above the sandy layer was equipped with two indicator of gages, with graduation 0,01 mm (model IG 10 MN) with accuracy class 1, designed to measure the linear dimensions of both absolute and relative methods, definitions of deviation from the desired geometric shape and arrangement of objects (tray and sample). According to the indicators tracked the shift of samples under the influence of the horizontally applied load, and to the right, next to the indicators, which were in a fixed state, was mounted the test sample on a sand base. After mounting the sample in the design position initial performance of indicators were obsered. For the experiments the samples were manufactured from gypsum with the above parameters. Given the different density, the same samples of concrete on 0,98 kg is heavier than gypsum. Thus, during tests the gypsum samples were uploaded on this value.

To the experimental sample the cable was attached to transfer the load. The cable (depending on tasks) was located between the sample and the block, either horizontally or with a slope, and behind the block – vertically downwards. One of the biggest factors, that affecting the operation of coatings is the slope of the surface. Maximum allowable slope when

the unit of pavements coatings are equal to 0,08, so the studies were carried out with the minimum, maximum and intermediate of slope values. On a horizontal surface, the slope is equal to zero, therefore, the intermediate slope is equal to 0,04.

To the lower end of the cable hanging the container on which incrementally was added the weight in steps of 0,01 kg. When the indicators showed values of the shift 1 mm, the cable with hanging on it loaded container was removed and weighed on an electronic Libra. The value of the horizontal load was measured. For all experiments the density of the sand layer before installation of the specimens was equal 1.65 g/cm^3 at humidity of sand 5 %. The results of the experiments are presented in the table (Tab. 1).

Table 1 – The longitudinal load applied to the coating of single FEM flat and corrugated shape of the base of the longitudinal shift element 1 mm

Number of experiment	Form of the base of FEP	The slope of the surface	The value of a longitudinally applied load, g
1	Flat	0	990
2	corrugated with one toothed element	0	1360
3	corrugated with five toothed elements	0	1950
4	corrugated with nine toothed elements	0	1720
5	Flat	0,04	690
6	corrugated with one toothed element	0,04	1340
7	corrugated with five toothed elements	0,04	1420
8	corrugated with nine toothed elements	0,04	1560
9	Flat	0,08	680
10	corrugated with one toothed element	0,08	1030
11	corrugated with five toothed elements	0,08	1180
12	corrugated with nine toothed elements	0,08	1200

The experimental results indicated that the tile with nine teeth, located on a horizontal surface, the resistance a horizontal load (load value at a fixed shift) is less than the tiles with five teeth, ceteris paribus. But compared to a tile with a flat base and tile with one toothed element in the base, the resistance at the horizontal load is higher. It is determined that the resistance at the horizontal load is higher in tile with five toothed elements in 49,2 % comparativly to tile with flat base, and in 30,3 % comparativly to tile with one toothed element. In the case, when the tile has five and nine toothed elements the resistance at the horizontal load should be larger for tiles with large number of teeth at the base. However, the experiments showed that the horizontal load which is perceived by the tile with five toothed elements, is in 11,8 % higher, than in the tile with nine toothed elements. This phenomenon can be explained by the fact that the zone of deformation under by the projecting parts of tile with nine teeth in the base overlap each other within the boundaries area of tile, and only the contour part of the base of tiles resists to horizontal load. Sand is under the base of tiles, between the teeth works, as a unit, and displacement of tile depends on the coefficient of adhesion of sand particles between them. In the case of tile with five toothed elements, partially the side faces of the pyramidal elements and the plane of the base tiles work.

If compare the results of the experiment on inclined surfaces, the resistance to the horizontal load is not much higher off the tiles with nine of toothed elements, than for tiles with five (9 % with a slope of 0,04 and 1,7 % with a slope of 0,08). This can be explained by the fact, that the perception of external influences by coatings located on sloping surfaces, greater volume of sand off FEP with the nine toothed elements in base is actevated, than the tiles with five teeth. If we compare the obtained parameters when the slope of the surface equal to 0,04 we see that the resistance to horizontal load in the tiles with the nine gear elements is 55,8 % is higher, than that of the tile with a flat base, and in 14,1 % higher than that of tiles with a single toothed element. If the surface slope is equal to 0,08 resistance to horizontal load in the tiles with nine toothed elements is higher in 43,3 % than in tiles with flat base, and in 14,2 % higher than in tiles with 6 single toothed element. On the surface with a slope of 0,08 resistance to horizontal load is higher by 29,1 % for tiles with one toothed element, than tiles with a flat base, and for coating with a slope of 0,04 – 41,7 %.

At increasing of the area of the FEP base large amounts of an underlying layer are utilized. To obtain the best option coating, the area of the protruding elements of corrugated base should be calculated so that deformation zones under them do not overlap [14, 15].

Research of the coatings from FEP with a modified geometric shape of the base under the influence of longitudinally applied load, have proved their advantages in comparison with traditional coatings. However, during operation, on the coating not only horizontal but also other types of loads (vertical, combined, etc.) are afected. In order to recommend in the construction industry the FEP coverage with base modified geometric shape, it is necessary more widely to study the characteristics of these coatings located on of horizontal and inclined surfaces, that requires further laboratory and field studies.

Conclusions:

1. Coatings with base corrugated form of single FEP, located on horizontal and inclined surfaces under the influence of longitudinal load, have been studied.

2. Values of the longitudinal load is the parameter which icharacterizes the ability to prevent the FEP shift are determinate.

3. It was established FEP with a modified geometric shape of the base more efficiently prevents the shift of coverage than the traditional FEP.

4. It was established experimentally that on the horizontal surfaces are more efficient a coating of the FEP with a corrugated base of the five toothed elements, and on the inclined surfaces – of the nine.

5. In order to recommend the FEP coatings with corrugated base in the construction industry it is also necessary to study the effect of other types of acting loads.

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