PERSPECTIVES OF USING DRY MIXES FOR REPAIR OF AIRFIELD CONCRETE PAVEMENTS

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Abstract. Repair of existing cement concrete pavements today carried out, mainly by overlapping layers of asphalt concrete. Thus cement concrete foundation defects in 1-3 years are reflected in the asphalt concrete surface layer. As a result, there is an inordinate increase in operating costs. The solution to these problems is the timely and quality repair of cement concrete pavements with the elimination of the causes of their destruction. For repair of concrete airfields, roads, that require to quickly open traffic on the repaired area, dry mixes are applied. Such mixtures are the most suitable for use in carrying out repair works.

Keywords: dry mixes, reinforced concrete frame structures, airfield cement concrete pavements.

Introduction

Airfield pavements are fundamentally different in constructive respect from other building structures. Modern airfield pavements should have high indices of strength, durability, evenness; wear resistance, surface roughness, stability against mechanical thermal influence of exhaust gases from jet engines, as well as against corrosive fluids, fuels and lubricants. Pavements should provide year-round, intensive and safe operation of aircraft. Therefore, the state of pavement should be so that aircraft flights could be performed in any weather conditions.

A fundamental factor in the choice of repair materials should match their physical and mechanical characteristics with the characteristics of the repaired surface. For many years, dry mixes used in the repair of concrete slabs.

The runways are linear structures characterized by small length, approximation to the relief, low solidity of upper layer which is concrete or asphalt pavement contacting over its large area simultaneously with two heterogeneous environments, namely natural environment (subbase) and arranged artificial foundation (Шелинин, Эккель 2005).

At that, load capacity and traffic volume of modern aircrafts, the technology of works performance and materials used in the construction of runways are non-compliance with the load on pavement, so in most cases, cannot carry these loads. As a result, deformations and deterioration of pavements occurred and there is a need for work performance after a minor operation period.

To eliminate these phenomena a widespread introduction of new materials and technologies that exist in the construction market of Ukraine is required.

To repair concrete and reinforced concrete surfaces of the runways deteriorated under mechanical loads and corrosion traditional, water-resistant and frost-resistant repair and rehabilitation mixtures of Ceresit, Siltek R-5, CPC S88 type and others are used. But these materials have significant disadvantages that must be considered taking into account the specificity of airfield pavements repair. In addition to the high cost of these materials should be considered small enough speed a set of durability.

In addition, it must be taken into account that the circumstances often require rapid, so-called “emergency repair” which is performed without rupture in traffic of flights, during the “technological window”, i.e. repair material should be quick-hardening and strong.

World experience of using repair mixes (Борисов 2009) showed that the most suitable mixes for repair of airfield pavements are dry, single-component, quick-hardening mixtures.

Features of Five Star Structural Concrete

The aim of the research was to determine the actual indexes of physical, mechanical and corrosive resistant properties of dry mixture of single-component quick-hardening repair material – Five Star Structural Concrete.

Structural concrete is the material of a new generation that has low shrinkage, retains corrosion inhibitors...
that during the repair work contribute to the formation of a stable bonding to the existing concrete surface and provide low chloride ion permeability promoting increased corrosion protection of steel and concrete structures and their frost resistance.

After applying the Five Star Structural Concrete structural integrity of repair surface is restored within a few hours (no more than 3 hours).

Due to this, Five Star Structural Concrete can be used for placement of thin layers (6 mm) and layers of significant thickness (30 mm) in one application.

Taking into account a wide range of positive properties of Five Star Structural Concrete, using of the material in the airfield branch will promote expanding the range of repair mixes, improving the quality and durability of the work.

Scientific research of Five Star Structural Concrete in pure form was conducted to determine the actual physical and mechanical properties and corrosion resistance for the application of a 6 mm thickness layer with the addition of granite crushed stone of grading from 1.25 mm to 0.63 mm from Hnivianskyi quarry for applying a layer of 30 mm thickness in the amount of 60 % by weight of dry mixture and the estimated amount of water.

Technical properties of water meet the requirements (DSTU B V.2.7-273: 2011).

The research program is shown in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Monitored characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compression strength</td>
</tr>
<tr>
<td>2</td>
<td>Adhesion strength with concrete</td>
</tr>
<tr>
<td>3</td>
<td>Tensile strength at bending (corrosion resistance)</td>
</tr>
</tbody>
</table>

Physical and mechanical properties of Five Star Structural Concrete were compared with the requirements of DSTU B V.2.7-126-2011 (DSTU P B V.2.7-126-2011).

The technology used for producing samples was based on a components mixing (dosing by weight) and water in a mortar-mixer for 3–4 minutes. Formation of samples started immediately after mixture preparation at a temperature of 20 °C. Samples gained strength in normal wet conditions.

For example, a defect in the form of cracks will continue its development if there is no strong basis, which excludes the deformation of the whole plate. A strong foundation is created during construction. Strengthening of the foundations can be performed during repairs, when coverage has been in operation for several years and under the influence of negative factors began to manifest various publishes defects and thus be aware that if the defect resulted from deformation of the base, then the crack, that appeared on the surface, is available in the base.

To eliminate cracks efficient way is to strengthening the foundation with injecting, performed without any destruction of cement-concrete cover and stops the vertical deformation of the coating.

Another defect is subsidence of cement slabs that occurs mainly due to technical defects in the dispersion of the base or under the influence of climatic factors. The elimination of this defect costly and usually consists in replacement plates because emptiness, which was formed under the stove almost impossible to fill a non-destructive method due to the lack of strong, waterproof materials with properties significantly increase the volume after usage (Solodkyi, Rusyn 2004).

The injection of some geopolymeric materials gives an opportunity to strengthen the base and correct operating defects in the cement coverages. It does not lose much money and not using labor-intensive technologies.

When injected into the base of geopolymer materials and sand-gravel mixture under pressure fill the space under the slab. After curing, form a solid array.

The process associated with the introduction of geopolymer materials in the space under the slab refers to the technological. It is a dependence of the rate of losses and the radius of the distribution of material, time of application and airfield construction.

The result of soil treatment is to increase its strength, adhesive and cohesive adhesion of the particles and resistance to frost.

After strengthening the array of soil significantly improves basic operational cement concrete construction. It is the modulus of elasticity.

Today the most common material for injection is a cement-silicate, silicate waste of pulp and paper industry, a rare hot bitumen (hot method bituminization), bitumen emulsion (method bituminization cold), synthetic resins. These materials are suitable for certain soil types.

Geopolymer resins based on polyurethane are versatile material that can be used for all types of soils – clay soils and clay, sand and gravel.

In addition, the elastic modulus of these materials is in the range of 15 to 85 MPa depending on the density and stored according to the elastic modulus of road – building materials, that is, while injecting when the average hardness of mass that will not change is strengthened. This enables these are the mechanical properties of soil that are needed at a particular site.

So geopolymer materials based on polyurethane when injected into the soil or macadam-sand foundation not only distributed in a short period of time, but also increases in the amount of filling voids in the plates that are strengthened in the direction of least resistance.

When the plate rises, and the void is filled with polyurethane resin the layer base, which is made up of soil from monotonous materials, is strengthening.

**Physico-chemical characteristics of dry mixes**

Research of determine the physical and mechanical properties of geopolymer materials, based on polyurethane, conducted in the laboratory of reconstruction of airports and roads.

To determine the durability and weather resistance were tested in artificial climate chamber type “Neutron” where samples were within 600 hours (equivalent to 5 years of service in the field operating conditions) under the action of ultraviolet rays, irrigation and so on. Due to the fact that geopolymer materials based on polyurethane...
have different density. For research were taken 2 materials – density of 150 kg/m$^3$ and 380 kg/m$^3$.

Corrosion resistance was determined by an accelerated method DIN 52 III (Koval et al. 2007) considering the change in tensile strength at bending and compression of samples that were kept in the solutions Na$_2$SO$_4$ (59.5 %) – sulfate corrosion and NaCl (35 %) – technical salt – chloride ion corrosion. To determine the physical and mechanical characteristics selected five samples of each material with the specified densities. Standard laboratory equipment used to determine these properties (hydraulic presses, freezers, desiccators). Material showed the best results with a density of 380 kg/m$^3$. The research results of physical and mechanical properties and corrosion resistance are shown in Table 2.

Table 2. Physical and mechanical properties of Five Star Structural Concrete (FSSC)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>FSSC without adding crushed stone</th>
<th>FSSC with crushed stone</th>
<th>Requirement of DSTU B.V.2.7-126-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression strength (R com), MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R com), MPa time of hardening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 hours</td>
<td>18.5</td>
<td>18.3</td>
<td>–</td>
</tr>
<tr>
<td>1 day</td>
<td>47.5</td>
<td>44.8</td>
<td>20.0</td>
</tr>
<tr>
<td>7 days</td>
<td>72.3</td>
<td>71.2</td>
<td>–</td>
</tr>
<tr>
<td>28 days</td>
<td>81.4</td>
<td>89.3</td>
<td>40.0</td>
</tr>
<tr>
<td>Adhesion strength with concrete (R ad), MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>14.5</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td>18.3</td>
<td>17.9</td>
<td></td>
</tr>
<tr>
<td>28 days</td>
<td>24.6</td>
<td>27.2</td>
<td>20.0</td>
</tr>
<tr>
<td>Tensile strength at bending (R ad), MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>–</td>
<td>3.75</td>
<td>2.0</td>
</tr>
<tr>
<td>7 days</td>
<td>–</td>
<td>5.90</td>
<td></td>
</tr>
<tr>
<td>28 days</td>
<td>–</td>
<td>8.50</td>
<td>4.0</td>
</tr>
<tr>
<td>Size change, % after 28 days of keeping wet</td>
<td>+0.03</td>
<td>+0.04</td>
<td>–</td>
</tr>
<tr>
<td>Size change, % after 28 days of keeping dry</td>
<td>−0.05</td>
<td>−0.05</td>
<td>–</td>
</tr>
<tr>
<td>Water resistance, MPa</td>
<td>7.5</td>
<td>8.0</td>
<td>–</td>
</tr>
<tr>
<td>Water absorption, %</td>
<td>0.1</td>
<td>0.1</td>
<td>–</td>
</tr>
<tr>
<td>Coefficient of frost resistance after 200 cycles, Km</td>
<td>0.920</td>
<td>0.943</td>
<td>No less than 50 cycles</td>
</tr>
<tr>
<td>Time of hardening, minutes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>beginning</td>
<td>20–30</td>
<td>20–30</td>
<td>–</td>
</tr>
<tr>
<td>ending</td>
<td>30–40</td>
<td>35–45</td>
<td>–</td>
</tr>
<tr>
<td>Time that is necessary for works performance, minutes</td>
<td>10.0</td>
<td>15.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

The results of tests fully meet the requirements of DSTU P B V.2.7-126-2001 (DSTU P B V.2.7-126-2011).

Table 3. Corrosion resistance of FSSC

<table>
<thead>
<tr>
<th>Indicators</th>
<th>FSSC without adding crushed stone</th>
<th>FSSC with crushed stone</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression strength (R com), MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>after keeping in Na$_2$SO$_4$ solution, time of hardening:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>46.4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>7 days</td>
<td>69.8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>28 days</td>
<td>78.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>after keeping in NaCl solution, time of hardening:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>45.2</td>
<td>–</td>
<td>3.50</td>
</tr>
<tr>
<td>7 days</td>
<td>70.6</td>
<td>–</td>
<td>5.70</td>
</tr>
<tr>
<td>28 days</td>
<td>81.4</td>
<td>–</td>
<td>8.40</td>
</tr>
</tbody>
</table>

In addition, the studies were conducted to determine adhesive qualities (roughness) of a runway with the applied layer of Five Star Structural Concrete in compliance with DSTU 3587-97 (DSTU 3587-97).

The study was conducted using a portable pendulum device MP-3 to determine adhesion coefficient on the surfaces with a layer of Five Star Structural Concrete of 6 mm, 30 mm thickness and the initial surface. The results of studies determining adhesive qualities (roughness) of the surface depending on the thickness of the applied layer of Five Star Structural Concrete are shown in Table 4.

Table 4. The results of studies determining adhesive qualities

<table>
<thead>
<tr>
<th>Surface</th>
<th>Requirements of DSTU 3587-97</th>
<th>Initial Surface</th>
<th>Thickness of FSSC layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dry</td>
<td>wet</td>
<td>dry</td>
</tr>
<tr>
<td>Existing cement concrete surface (life time – 7 years)</td>
<td>0.35 0.37 0.37</td>
<td>–    –   –   –   –   –   –   –   –   –</td>
<td></td>
</tr>
<tr>
<td>Surface with the layer of Five Star Structural Concrete</td>
<td>–    –   –   0.42 0.41 0.44 0.43</td>
<td>–    –   –   –   –   –   –   –   –   –</td>
<td></td>
</tr>
</tbody>
</table>

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The results showed that at the application of the layer of structural concrete the surface roughness increases, especially when the applied layer is of 30 mm thickness, i.e. riding qualities of the airfield will be improved.

Conclusions

The obtained results show that Five Star Structural Concrete is durable, waterproof and frost resistant material ($K_{m}^{200} – 0.943$ with crushed stone and $K_{m}^{200} – 0.920$ without it) that is characterized by high adhesion to the existing surface which is repaired ($R_{zch}^{28} – 89.3$ MPa for a mixture with the addition of crushed stone and $R_{zch}^{28} – 81.4$ MPa for a mixture without crushed stone, $R_{zch}^{28} – 27.2$ MPa and $R_{zch}^{28} – 24.6$ MPa correspondingly.

Due to the rapid gaining of strength, water and corrosion resistance, technological using of Five Star Structural Concrete is important for airfield branch, especially at performing operational “emergency repair” in conditions of uninterrupted mode of flights during optimized hours (technological window) that will enhance quality, durability and cost-efficiency of performed works.

References

DSTU 3587-97. Roads, streets and railway crossings. Operational status requirements.
Борисов, С. М. 2009. Жестко о жестких покрытиях, Автомобильные дороги 3: 46–47.