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Investigation of Concrete Pavement Abrasion Resistance in Agro-Industrial Facilities Using Polystyrene Waste

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Abstract: *Concrete floor pavements in agro-industrial facilities operate under combined abrasion, impact, moisture and organic environmental exposure, which accelerates degradation of the surface layer and increases dust formation. The study evaluates the use of polystyrene waste dissolved in toluene as a polymer impregnation for strengthening concrete pavement surfaces. Concrete specimens of class C25/30 were produced using Portland cement PC I-500, quartz sand and crushed stone aggregate with a fraction of 5–10 mm; the water–cement ratio was 0.42–0.45. After 28 days of curing at +20 ± 2 °C and 95% relative humidity, control specimens and specimens treated with polystyrene impregnation were compared by abrasion, water absorption, open porosity and surface condition. The polymer solution penetrated into the capillary-porous structure of concrete to a depth of 1–3 mm and formed a denser hydrophobic surface layer. The abrasion index decreased from 0.8–0.9 g/cm² for untreated concrete to 0.3–0.5 g/cm² for treated specimens. Water absorption decreased from 12–14% to 8–10%, while open porosity decreased from 18–20% to 14–15%. The results indicate that secondary polystyrene can be used as a low-cost strengthening impregnation for concrete floors, improving wear resistance, reducing dust formation and extending service life under agro-industrial operating conditions.*

Keywords: *concrete, concrete floor, polystyrene, strength, water resistance, energy efficiency, precast elements, deformation, plasticity, technological process, abrasion.*

1. INTRODUCTION

Concrete pavements are widely used in industrial, storage and transport facilities of the agro-industrial complex because they combine high compressive strength, technological simplicity and the ability to withstand heavy mechanical loads. In agricultural buildings, however, the floor surface is not exposed to a single damaging factor. It is affected simultaneously by abrasion from vehicles and bulk materials, impact loads, moisture, cleaning water and aggressive organic environments. Under such conditions, the upper layer of concrete gradually loses density, dust formation increases and the service life of the pavement decreases [1–4].

The durability of concrete floors is determined not only by the strength class of the material but also by the microstructure of the surface layer. Increased open porosity promotes the penetration of water and chemically active substances into the cement stone. This process creates favourable conditions for microcrack formation, local scaling and progressive abrasive wear. Current approaches to improving the performance of concrete floors include optimized mix design, surface hardeners, toppings, hydrophobic treatments and polymer impregnations [5–8].

Polymer impregnations are particularly relevant when the objective is to strengthen an existing or newly produced surface without changing the load-bearing structure of the pavement. Epoxy, polyurethane and acrylic compositions can densify the capillary-porous system of concrete and reduce dust formation; however, their use is often limited by material cost. The reuse of polymer waste, including polystyrene packaging waste, is therefore both a technological and environmental issue. Previous studies indicate that polystyrene dissolved in organic solvents can form a protective film inside the surface pores of concrete [9–10].

The research gap lies in the insufficient assessment of such recycled polymer compositions for concrete floor pavements operating specifically in agro-industrial facilities, where abrasion, moisture and organic contaminants act together. The objective of this paper is to determine the effect of polystyrene waste-based impregnation on abrasion resistance, water absorption, open porosity and operational durability of concrete pavements used in agro-industrial complex facilities [11–12].

2. MATERIALS AND METHODS

The study was designed as a comparative laboratory experiment. Two groups of specimens were prepared: untreated control concrete specimens and concrete specimens treated with a polymer impregnation based on polystyrene waste. The comparison focused on the surface characteristics that most directly influence the serviceability of concrete floors: abrasion index, water absorption, open porosity, dust formation and visual surface condition after testing [13–15].

A total of 12 concrete specimens of class C25/30 were prepared for the study, including 6 control specimens and 6 specimens treated with polystyrene impregnation. The specimens had dimensions of 100 × 100 × 100 mm and were cast in steel moulds. Compaction was performed using a vibrating table, after which the specimens were cured for 28 days at a temperature of +20 ± 2 °C and a relative humidity of 95%.

Concrete specimens of class C25/30 were produced using Portland cement PC I-500, quartz sand and crushed stone aggregate with a fraction of 5–10 mm. The water–cement ratio of the concrete mixture was maintained within 0.42–0.45. The specimens were moulded in metal forms and compacted by vibration. After moulding, they were cured for 28 days at a temperature of +20 ± 2 °C and a relative air humidity of 95% until reaching the design strength.

Figure 1. Concrete specimens for testing without treatment and with polymer impregnation.

The impregnation was prepared by gradually dissolving polystyrene waste in toluene under mechanical stirring until a homogeneous transparent solution with the required viscosity was obtained. To ensure complete polymer dissolution, the mixture was stirred for 20–30 minutes until all visible polystyrene particles disappeared. The amount of polystyrene waste was approximately 15 kg per 1 m³ of finished solution. The resulting impregnation exhibited high penetration ability, allowing it to effectively infiltrate the capillary-porous structure of concrete. Depending on the initial porosity of the concrete, the solution was applied to the surface in one or two layers. After solvent evaporation, the polymer filled the near-surface pores and formed a dense protective layer, improving the durability and performance characteristics of the concrete surface [16–18].

Before applying the impregnation, the concrete surface was cleaned of dust, cement laitance residues, and other contaminants. Depending on the initial porosity of the concrete and the condition of the surface layer, the solution was applied in one or two layers using a brush or roller. After application, the polymer solution penetrated into the near-surface pores of concrete to a depth of approximately 1–3 mm. During solvent evaporation, the surface layer became denser and a compact polymer film was formed, which reduced the open porosity of concrete, increased waterproofness, and contributed to decreasing the abrasion of the concrete coating under mechanical loading.

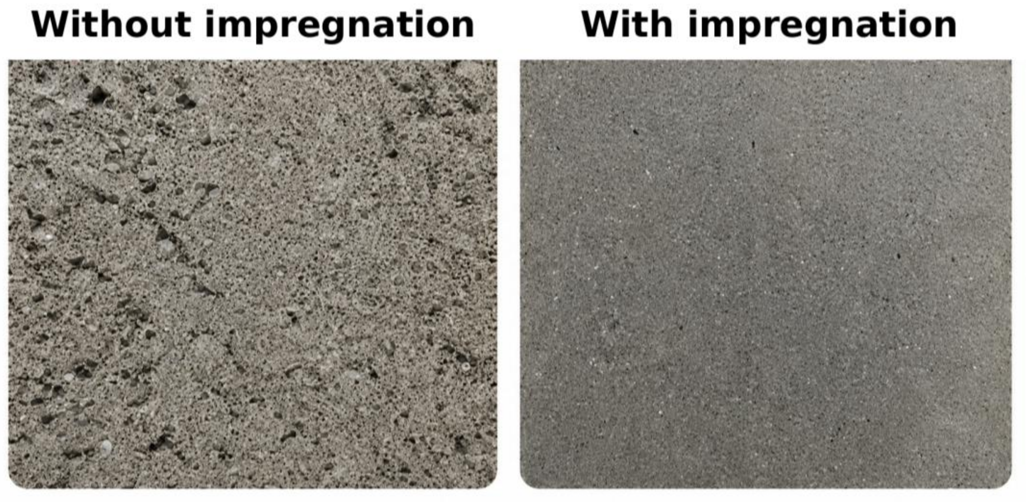

Figure 2. Visual comparison of concrete surfaces: (a) without impregnation; (b) after application of polystyrene impregnation

Abrasion resistance was determined in accordance with EN 13892-3 using an abrasion testing machine. Three specimens were tested for each series. The specimens were subjected to 10,000 abrasion cycles under a constant load. The mass of each specimen was measured before and after testing with an accuracy of 0.1 g, and the abrasion index was calculated as the mass loss per unit abraded area (g/cm²). Dust formation intensity was evaluated by visual assessment of the amount of loose particles generated on the concrete surface after abrasion testing and was classified qualitatively as high, moderate, or low. Surface condition was additionally documented by photographic inspection before and after testing.

Abrasion resistance was determined by measuring the mass loss of the specimen after abrasion. The mass of each specimen before and after testing was determined with an accuracy of 0.1 g. The length and width of the abraded surface were measured using a caliper, and the abrasion area was calculated. The abrasion index was determined according to Eq. (1).

$$C_t = (m - m_1) / A \quad (1)$$

where C_t is the abrasion index, g/cm²;
m is the mass of the specimen before abrasion, g;
m_1 is the mass of the specimen after abrasion, g;
A is the abrasion area, cm².

Abrasion resistance tests were carried out using an LKI-3 abrasion testing machine. The abrasion index was determined from the mass loss of the specimens after exposure to abrasive action and was expressed in g/cm².

Figure 3. LKI-3 Abrasion Testing Machine.

3. RESULTS

The treatment with polystyrene impregnation changed the structure and performance of the surface layer of concrete. The solution penetrated into the capillary-porous structure to a depth of approximately 1–3 mm, reduced the number of open pores and formed a continuous hydrophobic layer. The comparison of concrete porosity before and after treatment is shown in Fig. 4.

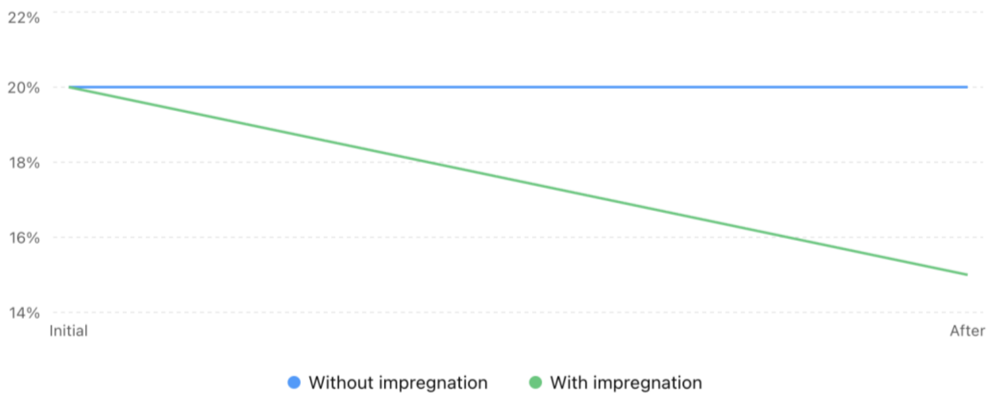

Figure 4. Porosity of concrete specimens before and after application of polystyrene impregnation.

The main physical and operational characteristics of the control and treated specimens are summarized in Table 1. The treated specimens demonstrated lower abrasion, lower water absorption and lower open porosity compared with untreated concrete. The visual assessment after testing also confirmed that the polymer-treated surface remained denser and did not show significant dust formation.

Table 1. Comparison of characteristics of concrete specimens.

Indicator	**Control specimens (without impregnation)**	**Specimens with polystyrene impregnation**
Abrasion, g/cm²	0.8–0.9	0.3–0.5
Water absorption, %	8–9	4–7
Open porosity, %	18–20	14–15
Dust formation intensity	High	Low
Surface condition after testing	Signs of destruction and dust formation present	Dense surface without significant destruction

The abrasion test showed that the polymer coating based on polystyrene waste significantly reduced the intensity of surface wear. After 10,000 abrasion cycles, the abrasion value of the coated specimens was 0.48 g/cm², whereas the control concrete reached 0.88 g/cm². The difference between treated and untreated specimens increased as the number of abrasion cycles rose, which confirms the strengthening effect of the polymer layer under repeated mechanical action.

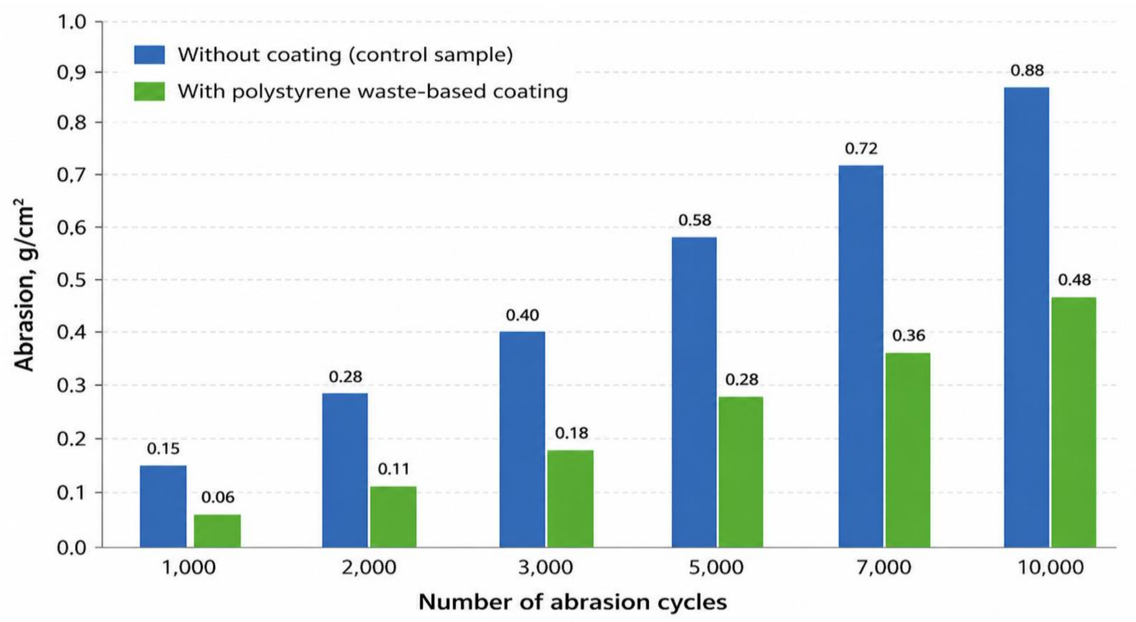

Figure 5. Comparison of abrasion cycles for uncoated floors and floors coated with a polystyrene waste-based composition in agro-industrial complex facilities.

4. DISCUSSION

The obtained results confirm that the main mechanism of improvement is the densification of the near-surface layer of concrete. By filling open pores and reducing capillary accessibility, the polystyrene-based composition limits the penetration of water and aggressive substances into the cement stone. This explains the simultaneous decrease in water absorption and abrasion index, as well as the reduction in dust formation observed after testing.

Compared with traditional industrial polymer impregnations, the proposed composition has a practical advantage because it uses secondary polymer raw material. This can reduce the cost of protective treatment and provide an additional route for utilization of polystyrene waste. The effect is especially relevant for agro-industrial facilities, where large floor areas are exposed to loaders, transport equipment, grain, feed residues and cleaning liquids.

At the same time, the study has several limitations. The tests were conducted under laboratory conditions on concrete specimens of one strength class and within a defined water–cement ratio range. Long-term resistance to freeze–thaw cycles, ultraviolet exposure, oil contamination and repeated chemical cleaning was not assessed in detail. The use of toluene as a solvent also requires strict compliance with occupational safety and ventilation requirements. Therefore, further studies should verify the durability of the coating under real operating conditions and compare it with commercial epoxy, polyurethane and acrylic impregnations [11–12].

5. CONCLUSIONS

The study established that concrete pavements in agro-industrial facilities are vulnerable to intensive abrasion, dust formation and moisture penetration because the upper layer directly absorbs mechanical and environmental loads. Surface treatment with polystyrene waste dissolved in toluene provides a measurable improvement in the operational characteristics of concrete floors.

The polystyrene impregnation penetrated into the concrete surface to a depth of 1–3 mm and formed a dense protective layer. As a result, the abrasion index decreased from 0.8–0.9 g/cm² to 0.3–0.5 g/cm², water absorption decreased from 12–14% to 8–10%, and open porosity decreased from 18–20% to 14–15%. The treated surface showed low dust formation and a denser condition after testing.

The use of polystyrene waste as a strengthening and hydrophobic impregnation is therefore a promising method for increasing the wear resistance and durability of concrete floors in agro-industrial complex facilities. The proposed approach also has environmental relevance because it supports the reuse of secondary polymer raw materials.

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