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TECHNOLOGICAL CONSIDERATIONS OF PERIODIC REPAIR WORKS OF CONCRETE INDUSTRIAL FLOORS

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A b s t r a c t

Concrete floors are among the elements in construction facilities whose design requires engineering experience, workmanship requires the maintenance of a technological regime, while during their operation it is necessary to conduct periodic repairs. Concrete floors are most often used as working and communication space in industrial facilities, and very often they are also a functional element in objects that are immovable monuments. Regardless of the place of installation, concrete floors require periodic maintenance works whose scope should each time be individually adapted to the current use of the object. Improper selection of maintenance work technology and incorrect application of technological solutions related to the renovation of floors can cause rapid deterioration of their technical condition, which may lead to the need to take them out of service, which in turn may result in the need to interrupt the use of the building facility, including production facilities of industrial facilities.

The paper presents a collection of practical information related to conducting periodic repair work on concrete industrial floors The article is a case study and addresses specific situations related to the loss of serviceability of concrete industrial floors.

Keywords: concrete industrial floors, repair, damage, reprofiling, expansion joints, scratching, shrinkage, cracks, surface curing, synthetic resin

1. INTRODUCTION

Floor laying works are among the most responsible and demanding in terms of workmanship in the construction industry, as their quality has a significant impact on the technical, functional and aesthetic value of the entire facility. The article discusses modern methods of repairing and renovating industrial floors, using grinding technology and polishing with the use of specialized chemical products that impregnate and strengthen floors and concrete substrates. The article provides practical information on repair work on concrete industrial floors.

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2. CAUSES AND EFFECTS OF THE DEGRADATION PROCESS OF CONCRETE INDUSTRIAL FLOORS

Over the past few decades, concrete floors have been dominant in production halls, warehouses, logistics and retail centers: monolithic surface cured - DST (Dry Shake Topping) systemically impregnated with acrylic or paraffin-based formulations, and floors finished in coating systems based on synthetic resins or concrete paints. Regardless of the finishing method, the surface of floors is subject to natural wear and tear over time, especially under heavy use [1-4, 8].

Degradation of the floor face first appears in the most heavily used areas, such as main traffic routes, transportation alleys, passageways and access to machinery and process equipment [5-6].

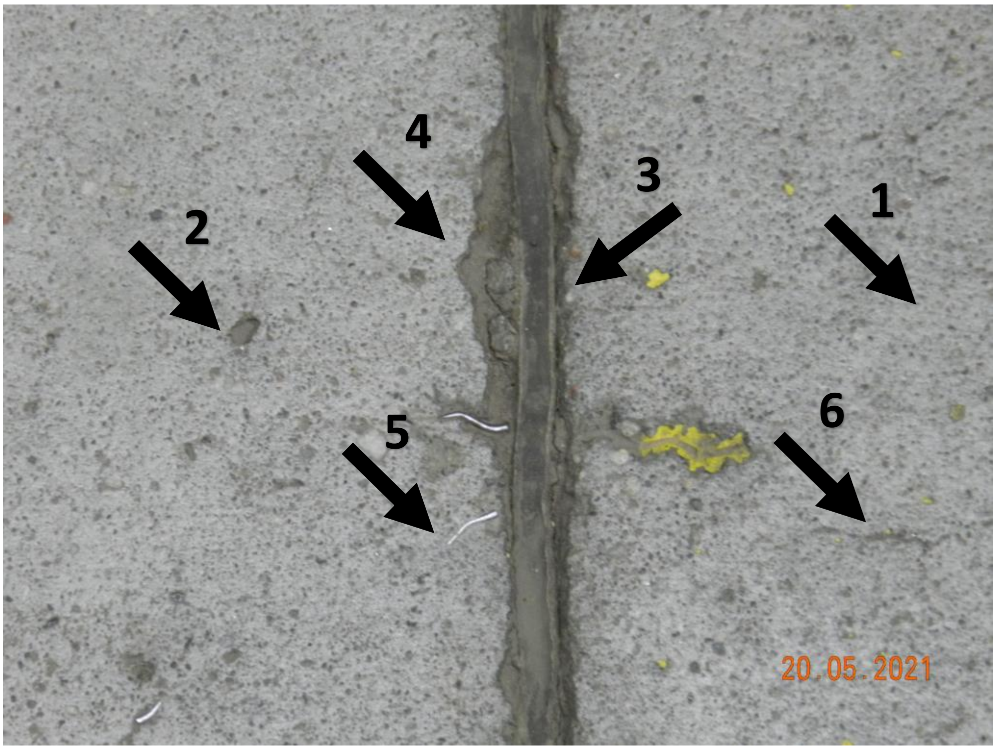

Fig. 1. Visible signs of wear of the top layer of the floor and filling of the shrinkage expansion joint (description of markings in the text) (photo by Sylwia Świątek-Żołyńska)

The fastest wear in concrete industrial floors is on coatings and surface coverings such as waxes, acrylics or paints, as well as thin-coat solutions of synthetic ryes applied by painting techniques [9-12]. In [Fig.1], the stages of floor wear are shown. Marked are: 1) abrasion and wear of the top layer of the floor, 2) aggregate losses, 3) separation of the expansion compound, 4) chipping of the edges of the expansion joints, 5) reinforcement fibers visible after wiping the top layer, 6) micro-cracks in the structure of the concrete.

Once the protective layer of the concrete floor is worn away, the degradation process of the visible concrete surface begins with the spalling and leaching of the aggregate-binding binder in the concrete substrate. This results in roughening and dusting of the pavement, and further exposes more and more of the aggregate grains. As this process progresses, localized damage such as topsoil detachment, cracking and spalling appear in increasing numbers [13-16].

If DST technology is used to finish a concrete industrial floor, i.e., a surface hardener is rubbed into its face, the degradation process will be delayed because after the protective coatings are wiped off, it is the hardened layer that will wear and wipe away, so to speak, protecting the concrete floor from deterioration [32-33]. If proper maintenance service consisting of periodic washing of the and protecting the floors with impregnating agents, local abrasion, increased dusting cavities and scratches in the floor face can be noticed after only a few years [17-18].

Indeed, when the first signs of wear on the hardened layer are noticed, it may make sense to refurbish the face of the floor in order to inhibit the degradation process, as well as to increase its strength by chemically hardening the concrete [9]. A refreshed, strengthened and protected floor will be able to serve without fail for years to come. Failure to take renovation measures at an early stage of industrial floor degradation, always leads to endless, costly repairs. Renovation and repair measures are necessary to maintain performance, regardless of the floor's construction technology and finish [33-34].

At this point, it is important to point out an important difference between floor face renovation after several periods of use and industrial floor repair [19, 20]. Floor face renovation is used to level the top layer, remove old finish coatings, re-impregnate it and/or protect it with protective coatings [23, 27]. The purpose of the measures taken is the chemical strengthening of the floor face, which leads to: restoring or improving the original performance, reducing wear (scuffing) of the pavement, and improving the overall aesthetics.

Repairs to industrial flooring, on the other hand, include repairing damage and primary defects that arose during the construction stage and during the warranty period, as well as defects and secondary defects that arose during the long-term operation of the pavement. The primary repair methods for industrial floors include activities including: injection and crack stitching, partial replacements of all or parts of the floor, surface repairs and restorations through the use of specialized repair technologies and materials, as well as the installation of new protective coatings [24-26, 28-31].

3. WAYS TO RENOVATE AND REPAIR CONCRETE INDUSTRIAL FLOORS

The technology for the renovation of an industrial floor includes several key steps carried out in order: repairing expansion joints (A), filling cavities (B), grinding and polishing the surface (C), and finally protecting it through the process of impregnating the concrete (D).

A. Expansion joints in floor slabs are extremely important because they help compensate for movements caused by temperature and load changes. The process of repairing expansion joints includes [21,22]:
   - Evaluate the condition of structural, contraction and perimeter expansion joints and determine the extent of damage.
   - In the case of shrinkage expansion joints, remove the old filling, clean the joints from dust, dirt and other contaminants to ensure good adhesion of the newly installed fill, and the application of a new expansion joint material resistant to the conditions of the facility.
   - For structural expansion joints (working seams) dowel joints, the course of action is the same as for contraction joints. Prefabricated steel structural expansion joints are individually evaluated for wear. In the case of significant mechanical damage, the part placed in the face of the floor is replaced without removing the dowel part embedded below. In more complicated cases or in the case of reconstruction of the object, a decision may be made to completely forge the expansion joint and make a new element.

B. Repairing defects in a concrete floor is essential to restore its evenness, functionality and appearance. The process begins with the removal of loose fragments of concrete and thorough cleaning of the areas of the resulting cavities. For filling cavities, cement-based, less often polymer-cement-based compounds are most often used. To ensure good adhesion of the repair mass, the repaired areas should be moistened with water or primed with suitable agents. The defects are filled with a repair mass, appropriately selected for the type of concrete and operating conditions. Depending on the size and depth of the defects, the mass is applied in layers, carefully compacting each layer. Finally, the repaired areas are leveled and smoothed so that they are level with the surrounding surface.

C. The process of grinding and polishing an industrial floor begins with preliminary grinding, which removes unevenness, old coatings and other defects. This is done using coarse diamond grinding discs. It then proceeds to the next grinding stages, gradually reducing the gradation of the diamond discs to smooth the surface and remove shallow scratches. Once sanding is complete, polishing is proceeded with diamond polishing discs of increasing gradation until the desired level of shine is achieved. Final polishing is carried out with natural bristle discs and appropriate polishing agents to achieve a smooth, shiny floor surface. Depending on the methodology adopted, the grinding process can be enriched with the application of silicate composite-based preparations, which permanently strengthen the concrete by chemical reaction with free calcium hydroxide.

D. Concrete impregnation is a key step that ensures the long-term protection of the floor. The process of impregnating concrete begins with a thorough vacuuming and cleaning of the floor to remove dust and other contaminants. The impregnant is then applied to the concrete surface using a microfiber mop or spray. The impregnant, usually silicate-based, deeply penetrates the concrete, reacts with calcium hydroxide, and over time forms a hard and compact structure. After the impregnator dries, the floor is polished again to give the effect of a smooth, shiny surface. Thanks to the impregnation, the floor becomes more resistant to stains, abrasion and penetration of liquids.

Industrial floor restoration technology includes comprehensive measures that restore the functionality, durability and aesthetics of the floor. Each step - from repairing expansion joints and cavities, to grinding
and polishing, to impregnating the concrete - is essential to achieve the best results. Regular maintenance and proper care ensure the long life of the industrial floor.

The following are case descriptions of concrete industrial floors that have not been subjected to periodic maintenance and protection during many years of operation. Various methods of restoration of concrete floors are presented, adapted to the extent of their damage and the intended use of the facilities in which they were built.

Example 1

Example 1 is a floor in several years of use, located in a manufacturing plant in a section for welding steel components (Fig.2, Fig. 3).

Fig. 2. Degraded concrete industrial floor (Example 1): visible wear of the top layer, mounting anchors left over from equipment removal, and shrinkage joint damage [38]

Fig. 3. Degraded concrete industrial floor (Example 1) during repair: damage inventory, removal of mounting anchors [38]

(a) (b)

Fig. 4. Degraded concrete industrial floor (Example 1) during repair: (a) removal of loose floor fragments, (b) removal of mounting anchors [38]

The floor in question was thoroughly cleaned and loose fragments of concrete were removed (Fig.4a). Next, anchors left over from the dismantling of machinery and equipment used in the hall were removed from the floor, using concrete discs (Fig.4b). In the next stage, the repair of cavities in the pavement was carried out (Fig.5).

(a) (b)

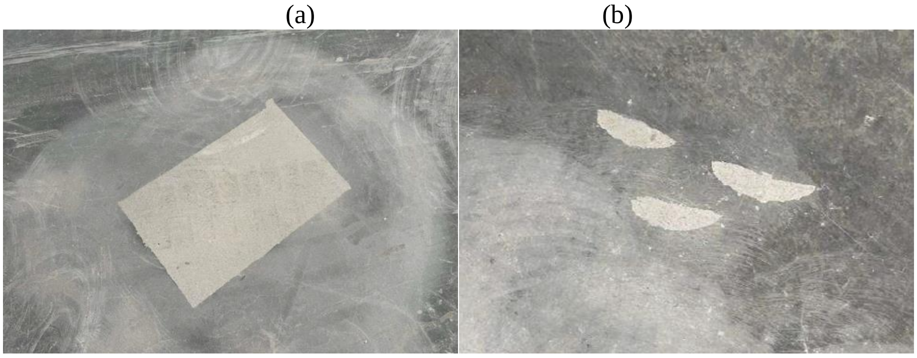

Fig. 5. Concrete industrial floor (Example 1) during restorations: (a) damaged areas brought to form shapes, (b) point defects [38]

Larger areas with irregular shapes were shaped into regular shapes by incising ~2cm deep and forging out redundant fragments with a hammer drill (Fig.5a). Surfaces to be restored were dusted off and moistened with water and grouted with a fast-setting mineral-based repair compound (Fig.5b).

Fig. 6. Concrete industrial floor (Example 1) during repair: making an addition to the basin formed after the removal of the process channel [38]

Filling the cavities was done with the excess material, which was then removed by grinding (Fig.6). [1]

(a) (b)

Fig. 7. Concrete floor grinding tool set (Example 1): a) grinding machine: b) machine planetario with visible metal segments [38]

After seasoning and drying of the repair material, which, depending on air humidity and ambient temperature takes 2-4 h, proceeded to coarse grind the entire surface with metal segments of gradation sequentially: 30 - 40 intended for hard concrete; then with metal segments of 60 -80 gradation to smooth out the scratches, and in the third step with metal segments of 120-140 gradation (Fig.7). At this stage, the grinding process was completed to remove the most degraded layer.

The next stage was the so-called “honeying” (honing), aimed at blurring the surface scratches created in the coarse grinding process. For this purpose, plastic diamond pads of gradation 50 are used. Then the floor was thoroughly vacuumed and washed with professional scrubbers, using water without detergents. A preparation based on silicate composites was applied to the substrate prepared in this way. After the product dried, i.e. about 1-2, further polishing work was proceeded with diamond pads of gradation successively: 100, 200, followed by double professional floor washing. After it dried, a silicate-based floor sealer and sealer was applied.

(a) (b)

Fig. 8. Concrete industrial floor (Example 1) after repair: a) visible areas of repair of cavities b): visible areas of repair after anchors [38]

Fig. 9. Concrete industrial floor (Example 1) after repair: general view and visible reconstructed and completed shrinkage expansion joints [38]

After drying, polishing was started with a white polishing pad using a high-speed polisher (Fig.8). To complete the work, the edges of the expansion joints were restored, and the expansion joints were filled with polyurethane compounds (Fig.9).

Thanks to a comprehensive treatment, the floor has regained its functionality and aesthetics, providing a durable and attractive solution for industrial spaces.

Example 2

Example 2 is a description of the process of renovation of an old floor, damaged and deteriorated during many years of use, in the state after dismantling the steel plates that form the top usable layer of the slab, as well as the platform for machinery and equipment (Fig.10).

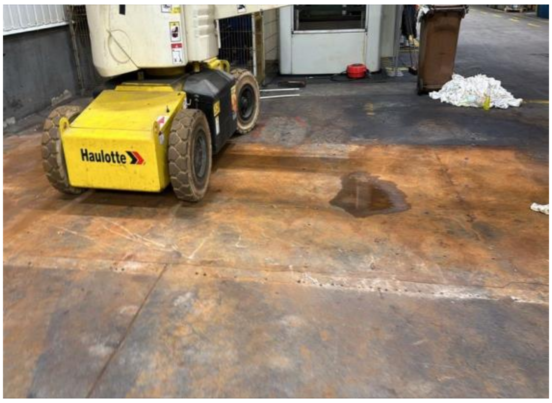

Fig. 10. Concrete industrial floor (Example 2) before repair: after removal of steel plates, visible rust mashing and discoloration [38]

The repair site required dismantling the steel plates and grinding and polishing the floor to level it and make it suitable for medium forklift traffic conditions. The renovation was carried out in the following steps. Dismantling of machinery and equipment eating into the facility was carried out, followed by removal of the top coverings in the floor in the form of steel plates. An inventory of anchors and cavities in the pavement was made. The anchors were then removed and the cavities repaired with a mineral system. Rough grinding was performed in three steps, sequentially with metal segments of gradation: 30 - 40, 60 -80 and in the third step with metal segments of 120-140 gradation.

In the next stage, surface scratches were obliterated, using plastic diamond pads with a gradation of 50. The floor was washed, vacuumed and impregnated using lithium silicate-based agents. For the final polishing of the floor, diamond pads of gradation successively were used: 100, 200.The floor was washed and cleaned of any residual dust created after grinding. A polymer-based sealer was applied to the floor to give it the desired performance characteristics. After it dried, the floor was polished with a white polishing pad using a high-speed polisher, and the joints were filled with expansion joint compounds.

(a) (b)

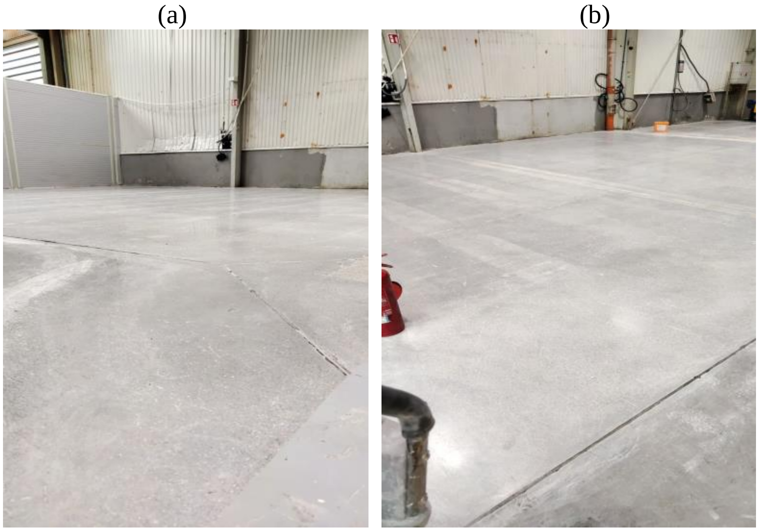

Fig. 11. Concrete industrial floor (Example 2) after repair: a) view of the areas of removed sheets, b) view of the polished surface and expansion joint fillings [38]

After the repair and renovation (Fig.11), the floor gained not only an aesthetic appearance, but also evenness. Before renovation, the local unevenness measured according to [35] was 9-11mm on a 2m patch after renovation was 3mm/2m, which corresponds to the increased performance standard of 5mm/2m). The smoothness of the surface implied as the degree of light reflection by the matte floor before renovation was estimated to be about 5-15%, after renovation more than 70%, where 100% light reflection occurs on mirrored surfaces. Naturally, this was also influenced by the removal of local dirt. The floor also gained increased abrasion resistance which before renovation was classified as Ar2 [36], after renovation: to the highest abrasion resistance class Ar0.5 [36]. Visible signs of quality improvement also include a reduction in the floor's dustiness, as well as a 45% reduction in its water absorption [37].

Example 3

Example 3 represents the renovation of a floor at an early stage of operation. The flooring in question was made without consideration of technical and technological aspects in very difficult weather conditions.

Fig. 12. Concrete industrial floor (Example 3) before renovation: arrows indicate cold joints [38]

During the execution of the floor, the hall was subject to temperatures exceeding 35°C and drafts. As a result, so-called cold joints formed on the floor surface, the floor was not fully smoothed to a smooth surface (Fig.12). During only a few months of operation, due to problems with cleaning, washing and aesthetic properties of the pavement, the investor decided to renovate the pavement in order to improve the overall aesthetics but also to restore it to a condition that would allow for normal exploration.

(a) (b)

Fig. 13. Concrete industrial floor (Example 3) after regeneration by polishing and impregnation process: a)general view, b) view of pavement treatment in the area of structural expansion joints [38]

Due to the low level of wear and tear from use, the grinding process omitted the use of metal pads, and the entire restoration process began with grinding with plastic diamond discs with a gradation of 50 for honing. The floor was then reinforced with a silicate composite-based impregnant, and final grinding was performed with discs with gradations of 100 and 200, which increased its resistance to abrasion, intensive washing (Fig.13).

Example 4

Another example is the floor renovation resulting from a change in the facility's function from manufacturing to storage after ~15 years of operation.

Fig. 14. Concrete industrial floor (Example 4) before renovation: damaged upper floor surface due to improper use of cleaning agents [38]

The ~6,800m^2 facility was in dry production, but leachate from machinery and equipment in the form of chemicals, oils and grease, permanently penetrated the floor structure (Fig.14). The floor required thorough washing and cleaning with specialized chemicals. Locally degraded parts required rough sanding, which took place on about 5% of the hall's surface. More than 6,000 anchors were removed from the floor, along with the repair of the areas after their removal. During the renovation work, it was found that all working expansion joints were subject to edge displacement and there was so-called slab keying associated with deformation and settlement of the substructure.

In the course of the work, a decision was made to repair the substructure and thus support the edges of the expansion joints by pressure injection, which was eventually carried out in the amount of ~1200 mb of expansion joints.

Fig.15. Concrete industrial floor (Example 4) during repair:
diagram of drilled holes for injection feeding [38]

The repair by injection consisted of drilling ~14 mm diameter holes in the floor along the working expansion joints (Fig.15). The holes were drilled to the full thicknesś of the floor alternately on both sides of the expansion joints. The distancé of the holes from the edge of the slab is ~30 cm, and the spacing between adjacent holes does not exceed 60 cm. At the corners of the slabs, it was recommended that the spacing be halved to maximize stabilization of the most sensitive areas.

Fig. 16. Concrete industrial floor (Example 4) during repair:
installation of packers and feeding of cement injection with a pump [38]

Control packers are made in the central part of the slab to monitor the consumption of the injectant (Fig.16). Then, through the drilled holes secured by the packers, the mineral cementitious liquid mass was applied using ą injection pump.

The liquid cement paste fills the spacé between the lower edgę of the floor, and the upper surface of the substructure. Manual control of the pressure and consumption of the material during application allows even filling of free spaces in the lower layers of the substrate and substructure under the floor.

(a) (b)

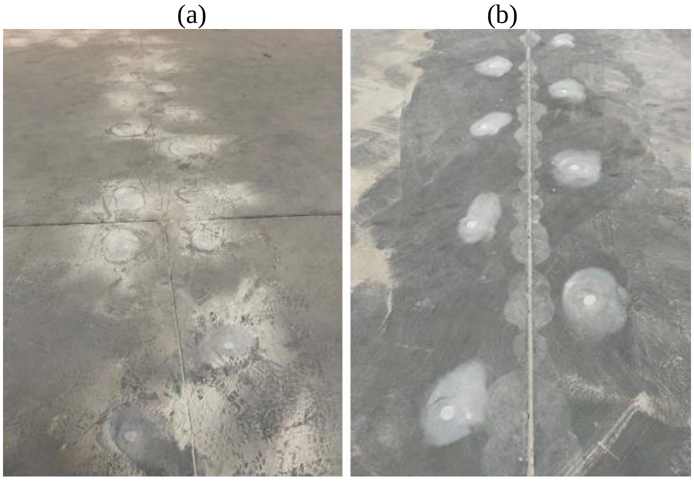

Fig. 17. Concrete industrial floor (Example 4) during repair at the stage of filling the injection holes: a) application of convex meniscus preparation, b) injection points after grinding to level the floor surface [38]

The next step was to fill the holes visible on the floor surface with ą applied injection compound or fast-acting material (Fig.17). The undoubted advantage of this technology is that the floor can be fully loaded 24 hours after the injection is completed.

(a) (b)

Fig. 18. Concrete industrial floor (Example 4) during repair: a) removal of degraded shrinkage joint fill, b) placement of new shrinkage joint fill [38]

(a) (b)

Fig. 19. Concrete industrial floor (Example 4) during repair: a) visible loss of expansion joint edge, b) spot repair of expansion joint edge with restoration of infill [38]

The facility also underwent replacement of expansion joint filling (Fig.18), along with spot repair of chipped edges (Fig.19).

After all repairs were made, the floor was subjected to a plastic pad sanding process in order to cover up surface scratches and micro-scratches visible in the face of the floor after wiping off the top finishing layer. The grinding was performed using plastic diamond pads with a gradation of 50. The floor was then thoroughly vacuumed and washed with professional scrubbers, using water without detergents.

(a) (b)

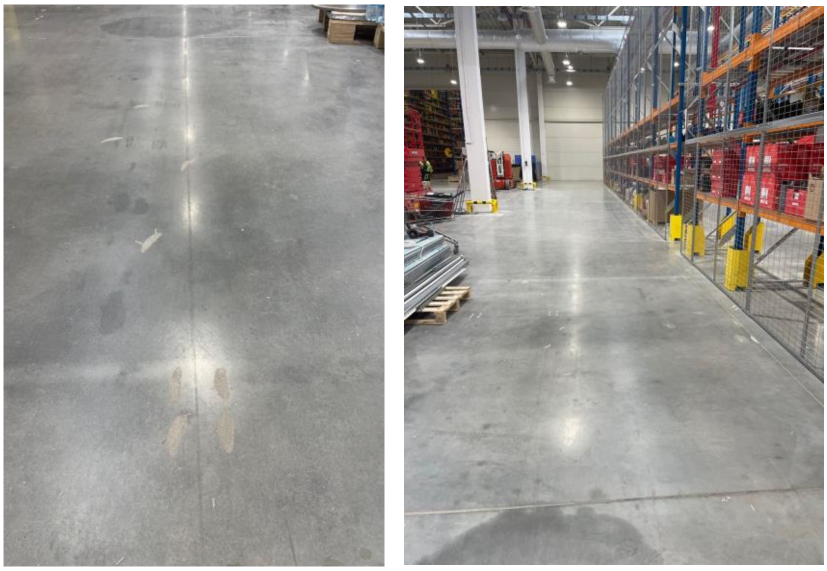

Fig. 20. Concrete industrial floor (Example 4) after repair: a) visible gutting areas after anchors were cut out, b) general view after the facility was converted into a warehouse [38]

A preparation based on silicate composites, which penetrates into the pores of concrete and works in molecular structures to strengthen and seal its structure, was applied to the substrate prepared in this way. The impregnant was applied using rollers and sprays. Grinding work continued with diamond pads of gradation successively: 100, 200, followed by the application of two professional floor washing. After it dried, a silicate-based floor sealer and sealer was applied and polished. The method used made it possible to strengthen the surface of the concrete and provide additional protection against dirt and damage (Fig.20).

4. CONCLUSION

Based on the information provided in the scientific and technical literature, technical literature, and taking into account our own experience, the following observations can be made:

- each floor should be considered individually, as there is no single effective method of repair and renovation, and the selection of renovation technology including chemicals and tools should always be preceded by a thorough analysis and inventory of the existing condition,
- very good results in industrial floor restoration work are obtained by grinding and polishing technology with segments and pads, regardless of what its finishing layers are,
- when using this technology, the key issue is the selection of appropriate tools (machines, segments, pads), which should be carried out on the basis of a test plot.

5. FINAL CONCLUSIONS

Renovation and secondary maintenance of concrete industrial floors is key to maintaining their functionality and extending their life. Regular maintenance and systematic repairs allow for early detection and repair of minor damage before it develops into major problems that can lead to costly downtime and shutdowns. Maintenance, including cleaning and waterproofing, increase the protection of the concrete floor's face against harmful operating factors, such as intense abrasion and mechanical loads caused by the movement of transportation equipment.

Renovation of concrete industrial floors using concrete grinding technology improves their appearance, which is not only aesthetically important but also functional because clean and well-maintained floors reflect light and brighten up the interior, as well as minimize the risk of slips and falls. Long-term maintenance of concrete floors in good condition, in turn, translates into lower operating costs, as costly repairs and replacements are avoided.

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Standards, Handbooks, and Guidelines

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