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Multidisciplinary Analysis of Pathologies in Industrial Rigid Pavements: Mitigation of Structural Risks and Optimization of Reinforcement Systems

Multidisciplinary Analysis of Pathologies in Industrial Rigid Pavements: Structural Risk Mitigation and Reinforcement Systems Optimization

Luís Gustavo Mendes Perecin - Bachelor of Civil Engineering from the Piracicaba School of Engineering.

Summary

This study investigates recurring pathological manifestations in reinforced concrete floors intended for industrial environments with high mechanical stress. It analyzes the interaction between the rheological properties of the concrete and the geotechnical conditions of the subgrade, focusing on the phenomenon of shrinkage and the instability of differential settlements. The research addresses prevention methods based on the introduction of polymeric fibers and prestressing, aiming to guarantee the durability and aesthetic and structural functionality of large manufacturing units.
Keywords: Reinforced Concrete. Industrial Floors. Structural Pathologies. Cracking. Civil Engineering.

Abstract

This study investigates recurrent pathological manifestations in reinforced concrete floors designed for high-stress industrial environments. It analyzes the interaction between the rheological properties of concrete and the geotechnical conditions of the subgrade, focusing on the phenomenon of shrinkage and the instability of differential settlements. The research addresses prevention methods based on the introduction of polymeric fibers and post-tensioning, aiming to ensure the durability and the structural and aesthetic functionality of large manufacturing units.
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Introduction

Contemporary industrial infrastructure demands high-performance pavements capable of... to withstand extreme static and dynamic loads from heavy machinery and flows. intensive logistics. Concrete, due to its versatility and high compressive strength, It has become established as the predominant material for such applications, however its non-inert nature... Subject to premature degradation when exposed to execution or design flaws. Understanding The technique of identifying the variables that influence the behavior of polished concrete is essential to avoid... The emergence of cracks and other damage that compromise factory operations and the integrity of assets. Financial assets tied up in construction.

This chapter proposes a scientific immersion into the fundamental causes of pathologies in floors. Industrial sectors, structuring a diagnosis based on precision engineering and soil mechanics. Through the analysis of visual and structural phonological parameters, the aim is to establish criteria. rigorous technological control measures from sub-base preparation to the critical curing phase and finishing. The transition to advanced reinforcement methodologies is emerging as an imperative for increase the lifespan of structures and reduce the incidence of costly maintenance that They often paralyze entire production chains.

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1. Dynamics of Shrinkage and Cracking in Industrial Concrete

Excessive cracking is the most significant technical disadvantage in Industrial concrete structures, a phenomenon that is difficult to eradicate completely. This process It often begins with plastic shrinkage, which occurs while the clay is still fresh. resulting from the accelerated evaporation of the mixing water before the material reaches strength. Sufficient mechanical strength. The restriction to the natural contraction movement of the plate, imposed by friction with The sub-base layer generates internal tensile stresses that exceed the incipient bearing capacity. resulting in macroscopic discontinuities on the finished surface.

Autogenous shrinkage, in turn, manifests itself through a reduction of free water in the capillary pores. to fuel the hydration reactions of the cement, without exchanges with the external environment. This The phenomenon of self-drying is exacerbated in high-performance concretes with low factors. Water/cement mixtures require careful planning of plasticizing additives to control rheology. from the mixture. When not mitigated, these fissures act as penetration channels for agents. Aggressive substances, such as chlorides and sulfates, trigger corrosion of the reinforcement and degradation. systemic of the concrete structure.

Additionally, the thermal variations resulting from the exothermic hydration reactions of Portland cement induces expansions and contractions that compromise the monolithic nature of the system. floor. The temperature difference between the core of the plate and its surface generates gradients of Deformation that can lead to warping of the edges of the slabs, affecting the leveling of the pavement. Strict control of the mix design and the application of vapor barriers are strategies fundamental for stabilizing the relative humidity within the concrete mass and reducing the amplitude of these thermal and hydraulic deformations.

Carbonation cracking occurs due to a chemical reaction between carbon dioxide. Atmospheric factors and the products of cement hydration reduce the pH of the matrix and remove its protective properties. natural steel. Although this process may cause a slight reduction in volume, it is compensated for by... expansions, it is critical for long-term durability, as it facilitates premature oxidation of metallic elements. Designers must therefore plan for adequate coverings and the use of Surface hardeners that seal capillary porosity, preventing gas migration and liquids seep into the pavement.

Finally, planning expansion and contraction joints represents the most effective method. to "induce" cracking in controlled locations, preventing the appearance of random cracks and disruptive. Delay in cutting these joints is a common executive failure that results in pathologies. serious issues, where internal tensions find paths of least resistance before intervention. Mechanical. The precision of the launching, leveling, and cutting schedule is the variable that defines the The final quality of an industrial floor requires coordination between the plant and the field team.

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2. Geotechnics and the Stability of the Base/Sub-base Interface

The integrity of a rigid pavement is intrinsically dependent on its ability to... The sub-base acts as the supporting element and ensures the homogeneity of the soil on which it is founded. distribution of forces, transforming the concentrated pressures of forklift wheels into Distributed stresses that the subgrade can withstand. Abrupt variations in compaction or the presence of Highly compressible soft soils can generate differential settlements that subject the plates to concrete subjected to bending stresses not foreseen in the structural design.

Preliminary geotechnical tests, such as the SPT sounding and the determination of the Index of California Bearing Ratio (CBR) is mandatory for the correct dimensioning of the thicknesses of layers. Recognizing the groundwater level prevents the phenomenon of rising damp. which can cause the detachment of polymer coatings and the degradation of the cement paste in base of the plate. Expansive soils represent an additional risk due to their volumetric movement. Induced by variations in humidity, it can lift parts of the floor, creating undesirable steps. together.

The process known as *pumping* , or pumping of fine soils, occurs when water The material present in the sub-base is expelled through the joints under pressure from moving loads. This mechanism removes gradually the fine material of the subgrade is removed, creating voids beneath the concrete slab that eliminate the Continuous support causes shear failure. The construction of a graded crushed stone base. Well-compacted soil-cement is the recommended technical solution to stop this process. to prevent internal erosion and ensure the longevity of the system.

In areas with low-resistance soils, settlement due to consolidation can be mitigated. through pre-loading techniques and the use of geodrains. These methodologies accelerate the expulsion. of interstitial water, allowing the soil to stabilize before the execution of the final pavement of concrete. If the construction schedule makes such techniques unfeasible, the project should migrate to the concept. of slabs on piles, where the load is transmitted to deep and stable layers of soil.

Standardizing the mechanical behavior of the foundation throughout the entire area. Pavement is the main objective of soil engineering applied to floors. Deficiencies in landfill and Failures in compaction are among the most frequent causes of pathological incidents that require complete demolition and restructuring. Therefore, strict monitoring of soil density and the Moisture control during earthmoving is a step as critical as the actual mixing of the soil. concrete for the final performance of the work.

3. Materials Technology: Special Concretes and Reinforcement Systems

The advancement of industrial construction introduced High-Performance Concrete (HPC). characterized by a compressive strength greater than 40 MPa and low porosity. Through the

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By using silica fume and superplasticizing additives, a high-density cementitious matrix is obtained. which significantly reduces the required thickness of structural panels. This material minimizes the Indirect costs related to formwork and concrete volume, in addition to increasing chemical resistance against Oils and solvents typical of industrial plants.

The introduction of metallic and polymeric fibers (polypropylene or nylon) transformed the A method for controlling cracking, allowing the replacement of welded wire mesh in various contexts. The fibers act as stress transfer bridges within the concrete mass, inhibiting the... Propagation of microcracks and increased structural toughness. For floors subjected to loads. Moderate synthetic fibers effectively combat initial shrinkage, ensuring a smooth finish. superficial, more complete and homogeneous.

Prestressed concrete represents the technological frontier for large pavements. dimensions without joints, using high-strength steel cables tensioned by jacks hydraulics. The pre-compression introduced into the system cancels out the tensile stresses resulting from Operational loading, enabling the execution of continuous "panels" that reduce the maintenance. This technique is ideal for automated logistics centers, where the absence of joints It minimizes wear and tear on forklift wheels and ensures the precise movement of robots.

On the other hand, the use of heavy concrete, with aggregates of high specific gravity such as Hematite is restricted to applications that require radiological protection or extreme stability. Although Less common in general logistics flooring, its durability against mechanical abrasion makes it a A viable option for steel industries or heavy material unloading areas. The success of these Special concretes intrinsically depend on precision in the mix design, avoiding segregations that They compromise the final resistance.

The bond between steel and concrete, fundamental for reinforced concrete, is ensured by Mechanisms of adhesion, friction, and mechanical anchoring of the ribs of the bars. In floors, the correct Protection of the reinforcement bars and adherence to the standard concrete cover prevent premature oxidation that would generate... The delamination of the concrete surface layer. The harmonious integration between the concrete matrix. and the chosen reinforcement system defines the ductility and operational safety of the pavement during its entire life cycle.

4. Surface Pathologies and Technical Finishing Procedures

Surface delamination or delamination is a critical pathology that manifests itself through Detachment of thin flakes from the floor surface after polishing. This phenomenon is frequently triggered by the premature execution of the finishing work with "helicopter" machines before The end of the concrete exudation process. The air and water trapped below the film. Sealed structures create horizontal voids that separate from the rock mass when subjected to impacts or

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thermal movement.

Abrasion wear results from heavy traffic of steel wheels or from falling objects. heavy materials, resulting in the loss of cement paste and exposure of the aggregates. The application of Chemical surface hardeners, based on silicates, react with residual calcium hydroxide. to form crystals that close the porosity and increase surface hardness. The polished finish, When performed correctly under strict flatness indices (FF), it facilitates cleaning and It reduces the accumulation of contaminants in pharmaceutical or food environments.

The presence of efflorescence and stains on the surface is an indication of salt transport. soluble through the capillary network of hardened concrete. Although they often only have a character aesthetically, they can indicate drainage problems or poor quality of the water used in the mixing process. of the mixture. Treatment of these occurrences requires mild mechanical or chemical cleaning, followed by sealing the pores to stop the upward flow of moisture that carries the minerals to the surface.

Adverse weather conditions, such as intense sun or strong winds during concreting, They accelerate the drying of the upper surface of the plate, causing differential shrinkage and warping. Protection with plastic sheeting and immediate initiation of wet or chemical curing are defensive measures. fundamental to ensuring that the hydration process occurs uniformly. Exposure to Rain during finishing is a fatal mistake that removes the surface binder, resulting in a A rough and crumbly texture that requires deep corrective polishing.

Repairs to delaminated areas must follow strict protocols that include cutting. geometric mapping of the affected area and removal of all non-adherent material. Filling with Epoxy or cementitious mortars stabilized with resin ensure deformation compatibility. and rapid release for industrial traffic. Substrate preparation by milling or blasting. It is the only way to guarantee the necessary chemical and mechanical anchoring so that the repair does not become... a new pathology in the short term.

5. Executive Methodology and Planning of Technological Cures

The concrete pouring plan is the master document that coordinates the flow of concrete mixer trucks. The use of jet pumps and the interval between work fronts. The application of concrete. Using pumps allows access to restricted areas more easily, but requires a specific route. Richer in fines to prevent clogging of pipes. The placement and screeding should to be conducted by specialized professionals, using vibrating screeds or laser levels. to achieve the projected flatness indices.

The technical vibration of concrete aims to eliminate voids and trapped air, ensuring the... Perfect compaction of the mass around the reinforcement bars and transfer bars. Porosity

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Excessive vibration resulting from insufficient vibration compromises mechanical strength and The structure's impermeability makes it vulnerable to chemical attacks. Trained teams must To monitor the homogeneity of the mass, avoiding the segregation of coarse aggregates that tend to... deposit at the bottom of the mold under excessive vibration.

The surface finishing phase, carried out by mechanical finishers ("helicopters"), must to be monitored through surface hardness testing or observation of seepage water. The objective The goal is to obtain a polished, vitreous concrete without altering the water/cement ratio through the improper addition of water. to facilitate the work of professionals. Precise leveling, verified by digital devices, ensures that there is no accumulation of water or difficulties in the movement of cargo vehicles. palletized.

Technological healing is perhaps the most neglected and, at the same time, the most vital step. for the performance of the industrial flooring. Wet curing, maintained for at least seven days through Using wet felt mats ensures complete hydration of the cement granules and minimizes... Thermal shrinkage. Alternatively, chemical curing by spraying with paraffin-based compounds. It offers a physical barrier against evaporation, but its application should be cautious on floors that... They will receive subsequent coatings.

Finally, the management of industrial construction projects must link productivity to rigorous standards. Technological control of materials and processes. The replacement of skilled labor with teams. Inexperience or negligence in the supervision of fck tests are determining factors in the emergence of of congenital pathologies. The adoption of standardized procedures and maintenance manuals for End users are guaranteed that the initial investment is preserved, achieving the project's lifespan. with maximum operational efficiency.

Conclusion

The detailed technical investigation throughout this chapter demonstrates that engineering Industrial flooring has evolved from a simple design process into a multidisciplinary science. complex. It became evident that the structural success of a reinforced concrete floor depends on absolute harmonization between the structural design, the technological specifications of the materials and the rigorous executive control in the field. Negligence in any of these steps, from the Compaction of the sub-base up to the exact time of joint cutting invariably manifests itself in Pathologies that degrade the economic and functional value of the building.

The mechanisms of plastic and hydraulic shrinkage, identified as the main vectors of Cracking requires preventative strategies based on additive technology and planning. The climatic impact of the launch. The introduction of modern reinforcement systems, such as metallic fibers and Prestressing emerges not only as a competitive advantage, but also as a technical necessity.

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to enable larger spans and reduce periodic maintenance. Mastering mechanical properties. The fundamental properties of concrete, especially its modulus of elasticity and adhesion to steel, are key. scientific basis that underpins the operational safety of mega-industrial projects.

From a geotechnical standpoint, it can be concluded that industrial flooring should never be analyzed. not in isolation, but as an integral system of the foundation soil. Understanding phenomena How consolidation settlement and pumping of fines *(pumping)* allow the adoption of measures Corrective measures taken beforehand prevent catastrophic failures due to loss of support. Standardization of support for... The basis is the guarantee that the calculated voltages will be distributed in a predictable way, preserving the Integrity of polished concrete against excessive bending stresses.

Regarding finishing surfaces, the analysis reinforces the great importance of *timing.* Operational measures to prevent the peeling or delamination of the surface layers. Control of The exudation process and the prohibition of water spraying during performance are golden rules that They separate excellent works from friable and porous pavements. The investment in flatness and Leveling directly impacts the end user's logistical efficiency, reducing wear and tear. fleets and increasing operator safety in the factory environment.

The role of preventive maintenance and active technical inspection is becoming established as the best long-term financial investment, given the extremely high cost of pathological therapies Corrective. Crack repair by injection or metal suturing, although effective when conducted... According to experts, it rarely restores the original vitreous aesthetic and often leaves permanent marks on the glass. floor. Thus, prevention through rigorous technological cures and adherence to deadlines of Strengthening safety standards should be a non-negotiable priority for any infrastructure project manager. industrial.

Brazilian technical standardization, represented by NBR 6118 and NBR 7583, offers the The legal and technical framework necessary to guide engineering decisions, however, experience Field practice is what allows one to interpret the nuances of climate and materials. The use of Laser levelers and predictive cost and performance modeling software represent the state. The art of civil engineering, raising the standard of governance in capital-intensive projects. The convergence between academic knowledge and market technological innovations is the way forward. for the construction of resilient and sustainable structures.

Finally, this technical treaty hopes to contribute to the dissemination of best practices in Brazilian civil engineering, fostering debate on the importance of standardization and... Skilled workforce qualification. The industrial sector is the physical support of the national economy. where industrial growth materializes; treating it with due scientific rigor is to guarantee the future of The country's productive infrastructure. That applied engineering with strategic, technical and financial vision. It continues to be the cornerstone of success for complex projects throughout the country.

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