

Experimental characterization and FEA-supported design of a jointless macro synthetic fibre reinforced industrial floor in Latin-America

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Abstract

Jointless industrial floors in warehouse buildings are increasingly becoming a standard solution rather than a special design approach. Nevertheless, a standardized design method for determining the maximum joint spacing of such floors is currently unavailable; existing guidelines provide only general recommendations. This paper reviews the European TR34 and the American ACI 360R design guidelines with a focus on joint spacing criteria.

To complement existing design approaches, a finite element model was developed and applied to assess the behaviour of a jointless industrial floor subjected to shrinkage and environmental effects. Material parameters were determined through laboratory testing, and time-dependent shrinkage relationships were derived from the experimental results. The numerical analyses were performed using the ATENA software and were used to support the interpretation of field measurements and observed floor performance.

The designed jointless floor, reinforced with an optimized dosage of synthetic macro fibers, was constructed and continuously monitored. Residual strength values, shrinkage behavior of the fiber-reinforced concrete, and longitudinal floor movements were measured on site and compared with numerical predictions. The presented case study illustrates the potential of combining experimental characterization and finite element modelling to support the design and assessment of jointless industrial floors.

Keywords

Industrial floor, FEA design, Reinforced concrete, Synthetic fibers.

1 Introduction

In recent decades, industrial floors have undergone significant evolution in response to the increasing operational demands of logistics and manufacturing facilities. Traditionally, concrete floors have been designed with control joints, whose primary function is to induce and control crack formation resulting from concrete shrinkage. These conventional systems have proven to be functional and widely implemented; however, they present important limitations related to maintenance, long-term durability, and performance under intensive traffic conditions. Joints, in particular, often become critical points of deterioration, leading to issues such as spalling, loss of load transfer, increased repair costs, and disruptions to logistics operations.

In this context, jointless industrial floors have emerged as an innovative alternative aimed at eliminating or significantly reducing the number of control joints, allowing the construction of large continuous concrete slabs. This approach not only enhances the structural integrity of the system but also improves operational performance by minimizing surface discontinuities. To achieve this behavior, various design and construction systems have been developed, including the use of high fiber contents—particularly synthetic macrofibers or steel fibers—post-tensioned slabs, and shrinkage-compensating concretes. Each of these systems addresses shrinkage and crack control through different mechanisms, such as increasing stress redistribution capacity, introducing internal compressive stresses, or compensating for volumetric changes in the material.

At the same time, the digital transformation and automation of logistics processes have imposed new requirements on industrial floors. The implementation of technologies such as Automated Guided Vehicles (AGVs), Very Narrow Aisle (VNA) systems, Warehouse Management Systems (WMS), Automated Storage and Retrieval Systems (AS/RS), and Autonomous Mobile Robots (AMRs) demands surfaces with stricter geometric tolerances, greater flatness and levelness, reduced vibration, and enhanced durability. In this context, the presence of traditional joints can negatively affect the precision, speed, and reliability of these automated systems, making jointless floors particularly attractive.

Despite their advantages, the design of jointless floors still presents significant challenges, particularly in determining the maximum spacing between construction joints and controlling shrinkage effects under varying environmental conditions. Existing design guidelines, such as TR34 (The Concrete Society, 2013) and ACI 360R (ACI, 2010), provide general recommendations; however, they lack detailed methodologies that explicitly incorporate the time-dependent behavior of concrete and its interaction with environmental conditions.

Within this framework, the present work focuses on a case study of a jointless industrial floor design supported by experimental testing and finite element assessment for the design of jointless industrial floors reinforced with synthetic macrofibers in Latin America. As a case study, this proposed assessment approach was applied to the CDN4 project for PiSA Farmacéutica in Guadalajara, Mexico, designed to operate with automated equipment (AGVs) under demanding performance requirements.

The project included a restriction on the use of steel fibers; therefore, synthetic macrofibers were adopted as a viable alternative, taking advantage of their benefits in crack control, durability, and compatibility with electrical conductivity requirements. The system consists of a fiber-reinforced concrete floor designed to achieve high flatness and levelness standards, incorporating a hardened surface layer (slurry) to improve wear resistance and electrostatic dissipation.

Prior to construction, testing and technical validations were conducted, including material characterization, evaluation of the workability of fiber-reinforced concrete, and implementation of a quality control plan during construction. Additionally, sampling campaigns were carried out to assess mechanical performance and shrinkage behavior. These results were used to calibrate the numerical model and to support the interpretation of field measurements obtained during the project, providing an initial assessment of the applicability of the modelling approach under real construction conditions.

1.1 Limitations, standards, and the real nature of concrete shrinkage in Latin America

In Mexico, considered as a case study, the control of concrete shrinkage is generally defined within a regulatory framework that, although it establishes criteria for the classification, production, and evaluation of materials, presents significant limitations when attempting to predict the real behavior of concrete under field conditions.

Mexican regulations, primarily associated with NMX standards (Normas Mexicanas) and their partial alignment with international references such as ASTM, establish guidelines for materials and testing procedures, among which the following stand out:

- NMX-C-414-ONNCCE (2017) for hydraulic cements;
- NMX-C-255 for aggregates;
- NMX-C-159 for specimen preparation and curing;
- NMX-C-173 (2010) for measuring the drying shrinkage of concrete.

Although these standards provide an adequate technical basis for material characterization, their approach is predominantly descriptive and focused on quality control rather than on predicting structural behavior.

In particular, Mexican regulations tend to classify concrete into categories such as Class 1 and Class 2, depending on application and required levels of control. However, this classification primarily follows a prescriptive approach, defining how concrete should be produced rather than how it should behave in terms of volumetric deformation.

Furthermore, there are no clear and uniform shrinkage limits (expressed, for example, as microstrain at specific ages), which results in high variability in acceptance criteria among projects. This lack of standardization is further intensified by the limited integration of shrinkage considerations into structural design, particularly regarding cracking behavior, joint design, and long-term durability.

Consequently, although the Mexican regulatory framework enables consistent material characterization, it presents important challenges when attempting to extrapolate these results to the actual performance of concrete under service conditions.

1.2 Influence of materials on shrinkage

Concrete behavior with respect to shrinkage is strongly influenced by its constituent materials.

In the case of cements commonly used in Mexico (Cement Portland Ordinary – CPO, Combined Performance Category – CPC, Cement Portland Pozzolana – CPP, Cement-Polymer Systems – CPS), their chemical composition and heat of hydration directly affect shrinkage evolution, particularly at early ages. However, current standards do not explicitly link cement type to expected performance in terms of deformation behavior.

Aggregates, on the other hand, play a fundamental role by acting as the rigid skeleton of concrete, controlling shrinkage magnitude through their elastic modulus, mineralogical type, maximum size, and gradation. Despite this, in practice their selection is often driven more by cost and availability criteria than by their contribution to the volumetric performance of the system.

As a result, even when advanced mix design methodologies such as the Shilstone approach (Shilstone, 1990) are applied, the final behavior of concrete can become highly variable if the interaction between aggregates, cement, and admixtures is not considered in an integrated manner.

1.3 Shrinkage as a time-, humidity-, and environment-dependent phenomenon

Although concrete shrinkage is commonly expressed as a laboratory-measured value, its real manifestation in the field responds to a far more complex system involving environmental, geometric, and construction-related variables that are not fully captured by traditional testing methods.

From a theoretical perspective, moisture loss in concrete can be described through diffusion mechanisms, such as those established by Fick's laws. However, this process is not static; rather, it evolves according to environmental conditions, resulting in a shrinkage trajectory dependent on both time and ambient relative humidity.

Concrete shrinkage should not be understood as a single intrinsic material property, but rather as the outcome of a dynamic system in which moisture governs evolution, time defines the trajectory, restraint transforms deformations into stresses, and the environment amplifies or mitigates the phenomenon.

Within this context, attempting to predict the real behavior of concrete – particularly joint opening or cracking – based solely on values obtained under controlled laboratory conditions implies assuming a scenario that rarely exists in practice.

1.4 Reinforcement systems for jointless floors

Jointless floors offer significant benefits for the operational performance of industrial flooring; however, they also present major challenges in design, planning, and on-site execution.

Some of the main aspects to consider in the construction of jointless floors include the control of concrete shrinkage, due to the inherent tendency of the material to contract (generating tensile stresses in larger slab panels), the long-term prediction of cracking caused

by service loads, and slab edge curling resulting from moisture and temperature differentials between the top and bottom surfaces of the slabs (Juhász and Schaul, 2023).

Therefore, given the particular characteristics associated with these flooring systems, it is necessary to implement structural reinforcement systems capable of counteracting these phenomena, which otherwise lead to different types of distress and pathologies.

The primary reinforcement systems used for jointless floors in Latin America include heavily reinforced steel slabs, post-tensioned steel tendons, as well as steel and synthetic macrofibers.

Among the advantages of using BarChip MQ58 synthetic macrofibers as structural reinforcement in jointless floors are their contribution to compensating concrete shrinkage in the plastic state, control of crack propagation and crack width in the hardened state (maintaining crack widths below 0.5 mm), provision of residual strength, and reduction in labor costs due to shorter placement times for reinforced concrete.

1.5 Fiber-reinforced concrete testing under EN 14651

To evaluate fiber performance in concrete, a beam testing methodology defined under EN 14651 is commonly used (with specimen dimensions of 150×150×550 mm). This test measures the flexural tensile behavior of fiber-reinforced concrete through the application of a central load on the specimen. The standardized methodology provides a procedure for evaluating properties such as post-cracking strength, residual load-bearing capacity, and the deflection behavior of fiber-reinforced concrete beams under controlled crack opening at the lower central section of the beam (EN 14651, 2007).

The determination of flexural tensile strength under this standard is performed using a closed-loop servo-controlled hydraulic testing machine, applying a three-point bending load to the specimen at an average deflection rate within the range of 0.05 to 0.2 mm/min, until a crack mouth opening displacement (CMOD) of 4 mm is reached at the bottom notch, as illustrated in Fig. 1.



Figure 1: The beam test setup was performed according to EN 14651

1.6 Experimental testing of fiber-reinforced concrete – Montevideo test

Another methodology used to evaluate fiber performance in concrete is the cube test governed by the Montevideo experimental procedure (with specimen dimensions of 150×150×150 mm), which measures the behavior of the composite material under indirect tensile loading generated through compression. This is achieved by applying a wedge load in

the upper notch while providing partial support through a slender steel plate at the bottom of the specimen. This standardized methodology provides a procedure for evaluating properties such as post-cracking strength, residual load-bearing capacity, and the indirect tensile behavior of fiber-reinforced concrete under the opening of an induced crack at the top surface of the cube (Segura, et al., 2024).

The determination of compressive-induced tensile strength under this experimental procedure is carried out using compression testing machines commonly available in concrete quality control laboratories. A compressive load is applied through the slender support and wedge onto the specimen at an average displacement rate of 0.5 mm/min, until a crack mouth opening displacement (CMOD) of 4 mm is reached at the upper notch, as illustrated in Fig. 2.



Figure 2: Cube test setup according to the Montevideo method

2 Designing methods of industrial floors

2.1 TR34

Current design methodologies, such as TR34 (The Concrete Society, 2013), provide solid foundations for the dimensioning of industrial floors by considering loads, service conditions, durability, and shrinkage control, allowing both traditional jointed systems and large-panel or jointless floor solutions to be addressed.

However, they present relevant limitations. Concrete shrinkage is an unavoidable phenomenon; therefore, it is not possible to completely eliminate the risk of cracking nor entirely dispense with joints. In traditional systems, deterioration tends to concentrate at the joints, affecting load transfer and increasing maintenance requirements; whereas in jointless floors, although these critical points are reduced, uncertainty associated with restraint-induced cracking increases.

Additionally, factors such as environmental conditions, interaction with the subbase, and the time-dependent behavior of concrete cannot always be predicted accurately within current design approaches. This, together with the limited coverage of some advanced systems, highlights the need for more comprehensive methodologies, particularly in response to the higher performance demands arising from automation in modern industrial facilities.

2.2 ACI 360R

Another widely used methodology for the design of industrial floors is the ACI 360R (ACI, 2010) design guide, which provides technical recommendations for the analysis and design of concrete slabs supported on ground.

This methodology is based on Westergaard's theory and considers as a fundamental design principle that the concrete slab and the supporting soil act as a global integrated system, in which the soil behaves as an elastic support that generally distributes the applied loads.

The design objective under this methodology is to determine slab thickness, slab dimensions, load transfer capacity, crack control strategies, and the type of global reinforcement that enables the concrete to withstand the structural demands imposed on the floor.

Among the capabilities of this methodology is the design of slab thickness for different loading typologies, the analysis of load applications at various locations (such as interior, edge, and corner positions), the provision of recommendations for joint spacing, and guidance on the use of different types of structural reinforcement.

However, several limitations are associated with this methodology. It does not establish a specific design procedure for jointless floors (with joint spacing greater than 7.5 m), does not explicitly consider loads generated by automated equipment (such as Automated Guided Vehicles, AGVs), and generally adopts higher safety factors compared to other industrial floor design methodologies (such as TR34). Finally, it relies on equations derived from the Westergaard model, which simplifies the actual behavior of the soil-slab interaction.

For this reason, given the limitations of the industrial floor design methods currently used in Latin America, the adoption of viable alternatives, such as numerical analysis, becomes essential to achieve a more accurate approximation of the actual behavior of the floor structure and, consequently, to optimize resource utilization

2.3 Numerical analysis

The ultimate limit state (ULS), as defined by design standards, corresponds to the condition in which the structure is no longer capable of carrying additional loads. In the case of industrial floors, this condition is difficult to define, as failure cannot be identified as clearly as for structural elements such as slabs. Design standards addressing the ULS are typically based on the flexural and shear resistance of the floor; however, these do not necessarily coincide with the actual load-bearing capacity of the system. Consequently, compliance with the prescribed limit values given in the relevant guidelines is required when assessing the ULS.

In contrast, the serviceability limit state (SLS) represents a more relevant criterion for industrial floors. Failure in this context is more reasonably associated with deformations and crack widths that impair functionality. However, current guidelines provide limited guidance for the evaluation of these parameters, particularly in the case of jointless industrial floors. Therefore, the structural assessment was carried out at the SLS using finite element analysis, considering characteristic values for loads and mean values for material properties.

The finite element analysis was performed using the ATENA software (Cervenka Consulting, 2026). The material model is based on the Willam–Menétrey failure criterion (Menétrey and Willam, 1995), while the effect of fiber reinforcement was incorporated using the modified fracture energy method, as described in detail in *fib* Bulletin 117 (*fib*, 2025). The subbase beneath the slab was also modeled using three-dimensional finite elements, connected to the slab with an interface element. The subbase was modeled using a Drucker–Prager material model. The subgrade was represented by nonlinear springs calibrated based on the determined bedding parameters (Fig. 3).

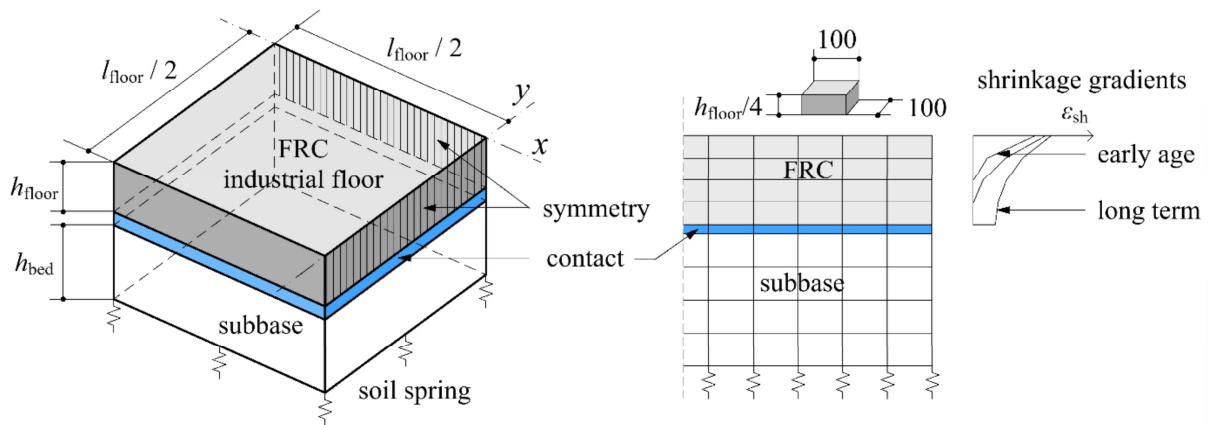


Figure 3: Finite element model of the floor

Time-dependent loading and shrinkage of the slab were introduced through sequential analysis intervals: in the first interval, self-weight was applied; in the second interval, initial shrinkage was introduced, accounting for an assumed cross-sectional gradient; in the third interval, the full service load was applied; and in the fourth interval, the remaining shrinkage was considered. These intervals represent actual time-dependent processes. The ultimate shrinkage value was obtained from experimental testing, while the evolution of the shrinkage gradient over time was determined based on environmental conditions – primarily relative humidity – and an estimated diffusion coefficient.

By applying both loads (self-weight and imposed loads) together with shrinkage effects, the crack pattern, crack widths, and deformation response of the slab were obtained. The resulting crack widths and deformations were found to be within acceptable limits, with a maximum crack width of 0.275 mm and a maximum deformation of 2.86 mm (Fig. 4).

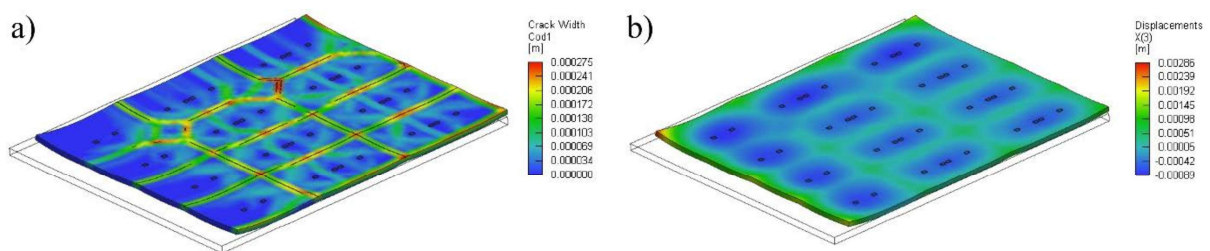


Figure 4: Results of FEA a) crack width and b) displacements

3 Design challenges of jointless industrial floors

3.1 Nonlinear hygrometric path

Ambient relative humidity is not constant; it varies with daily and seasonal cycles, continuously modifying the moisture gradient within the concrete.

This implies that shrinkage evolves nonlinearly over time and that concrete does not necessarily follow the theoretical curve originally predicted.

3.2 Difference between theoretical, measured, and observed shrinkage

There is a fundamental disconnect among three levels of analysis:

- Theoretical value, based on idealized diffusion and hydration models, represented as a continuous curve over time.
- Laboratory testing (prisms/bars), performed under controlled conditions, with simplified geometry and minimal restraint.
- Field behavior (joint opening / cracking), resulting from real conditions that include movement restraint, thermal and moisture gradients, subbase interaction, and construction sequencing.

Joint opening measured in the field does not represent shrinkage alone, but rather the integrated response of a complex system in which multiple phenomena act simultaneously.

3.3 Phenomena not replicable in laboratory conditions

Conventional shrinkage tests do not capture critical conditions present in real construction environments, such as:

- moisture gradients through the slab thickness;
- differences between top and bottom surfaces (curling/warping);
- friction with the subbase (with or without polyethylene layers);
- partial or total restraint to movement;
- thermal history of the element;
- variability in curing processes.

Therefore, laboratory testing represents an idealized behavior, whereas field conditions reflect a restrained, heterogeneous system that continuously evolves over time.

3.4 Advanced variables and limitations in current modeling approaches

Beyond the differences between theoretical values, laboratory testing, and field behavior, there exists a set of fundamental variables that govern the actual evolution of shrinkage and that are not yet fully defined or standardized within current regulatory frameworks or conventional design methodologies.

Among these variables are:

- the concrete diffusion coefficient, which governs the evolution of moisture content over time and its distribution within the section;
- the viscoelastic behavior of the material, including creep and relaxation phenomena in both cracked and uncracked states;
- the time–shrinkage relationship, particularly in scenarios where the rate of moisture loss is not constant;
- real loading conditions over time, which are often not clearly defined during the design stage;
- environmental conditions, including relative humidity and temperature;
- convection and evaporation mechanisms that determine the rate of surface moisture loss.

Additionally, in fiber-reinforced systems, an additional question arises regarding the long-term behavior of the composite material, particularly concerning creep and relaxation within cracked sections.

3.5 Implications for design and prediction

Even when an optimized mix design and laboratory-measured shrinkage values are available, direct extrapolation to field behavior introduces a significant degree of uncertainty.

This occurs because theoretical values lose predictive capability when the interaction among material properties, environmental conditions, and boundary conditions is not incorporated.

The inclusion of these variables within predictive models requires not only advanced formulations but also simulation tools capable of representing system evolution over time, such as approaches based on finite element analysis (FEA), which must be calibrated using real-scale data.

3.6 Conceptual framework and need for advanced modeling

The analysis presented in Sections 3.1 and 3.3 highlights a fundamental gap between current industrial floor design methodologies and the physical mechanisms governing concrete behavior in real service conditions.

Design guides such as TR34 (The Concrete Society, 2013) and ACI 360R (ACI, 2010) provide robust engineering frameworks for slab dimensioning, load analysis, and serviceability considerations. However, these methodologies rely primarily on simplified assumptions regarding shrinkage behavior, soil–structure interaction, and environmental effects. As a result, shrinkage is typically incorporated through empirical factors or prescriptive joint spacing recommendations rather than through explicit simulation of the governing physical processes.

Conversely, the behavior described in Chapter 3 demonstrates that concrete shrinkage is not a single material property but a coupled, time-dependent phenomenon influenced by moisture diffusion, environmental variability, structural restraint, and viscoelastic material response. The discrepancy between theoretical predictions, laboratory measurements, and field observations indicates that conventional analytical approaches cannot fully capture system evolution over time.

This mismatch becomes particularly critical in jointless floor systems, where the reduction of joints transfers uncertainty from discrete locations (joints) to distributed mechanisms such as restrained deformation and cracking development.

Therefore, a design methodology capable of integrating material behavior, environmental boundary conditions, and structural response within a unified framework is required. Numerical approaches based on advanced finite element analysis (FEA) provide a suitable platform for this integration, allowing simulation of moisture-driven deformation, stress redistribution, and long-term performance under realistic conditions.

The present study provides an initial investigation into the application of finite element modelling techniques for incorporating these coupled mechanisms and assessing the behaviour of jointless industrial floors under Latin American environmental conditions.

4 A Mexican case study

4.1 CDN4 Project – PiSA Farmacéutica

The industrial floor of the CDN4 project for PiSA Farmacéutica in Guadalajara, Mexico, was designed considering the specific Floor Requirements for operation with automated equipment (AGV) and constructed in accordance with a design developed by JKP STATIC and Monofloor, as a high-performance system intended for demanding industrial conditions.

Within these Floor Requirements, the recommendation to avoid the use of steel fibers in the flooring system was also included. Therefore, the use of macrosynthetic fibers was analyzed as a viable alternative to this restriction, due to their advantages in terms of crack control, durability, residual strength, and compatibility with conductivity requirements and automated system operations, as they do not generate magnetic interference or corrosion-related risks.

The design provides high structural capacity to withstand concentrated and repetitive loads, as well as strict control of flatness and levelness, which is essential for the proper operation of automated equipment. Additionally, the design aims to minimize the impact of joints, maintain nearly zero slopes, and ensure adequate friction conditions, supporting continuous, precise, and safe operation.

The constructed system corresponds to a fiber-reinforced concrete floor, placed with laser-guided leveling control and finished with high-precision surface treatments. As a key element, a hydrated layer (slurry coat) of mineral hardener was incorporated, applied fresh-on-fresh with an approximate thickness of 3.7 mm, improving wear resistance and surface quality.

The placement process of this layer consists of preparing the hardener as a fluid mortar, applying it continuously over the fresh concrete, integrating it through mechanical troweling, and ensuring controlled curing. Additionally, this layer is connected to the grounding system, enabling compliance with the electrical conductivity requirement of the floor ($RE < 10^6$ ohm).

Overall, the floor is characterized by high flatness, durability, surface strength, and electrostatic dissipation capacity, meeting the operational requirements of the project (DS Automotion GmbH, 2021; DS Automotion GmbH, 2023).

Prior to construction, testing and technical validations were carried out to ensure system performance from the design stage. These included determining the physical properties of aggregates used for concrete production, as well as evaluating the workability of fiber-reinforced concrete both at laboratory scale and through on-site industrial trials, with the objective of verifying its behavior during placement and finishing.

Additionally, a quality control plan was established to ensure proper system execution, incorporating best practices throughout all stages of the construction process, including fiber dosing and addition, mixing, transport, placement, leveling, surface finishing, and curing of the concrete slab. This control was key to ensuring material uniformity, proper integration of components, and compliance with the floor performance requirements.

As part of this comprehensive quality assurance approach, criteria were also defined for specimen sampling and testing procedures for fiber-reinforced concrete, which are presented and developed in the following section.

4.2 Specimen sampling and results

For the present Jointless Floor project in Mexico, three beam sampling campaigns were conducted for control testing (in accordance with EN 14651), two sampling campaigns of cubes and beams were carried out for a research project in collaboration with Universidad Nacional Autónoma de México (UNAM), and finally two sampling campaigns were performed to evaluate the shrinkage of concrete placed on site (in accordance with NMX C173).

The results obtained from the control samples tested at the Mexican Institute of Cement and Concrete (IMCYC) for the macrofiber-reinforced concrete used in this project are shown in Table 1. These results ensure average values exceeding the residual strength parameters used in the model iterations for the ATENA software applied to the structural design of the jointless floor in Mexico, with f_{R1} , f_{R2} , f_{R3} , and f_{R4} values of 1.65, 2.00, 2.35, and 2.50 MPa, respectively.

Table 1: Residual strength values from control tests performed at IMCYC for beams

Sampling	Campaign number	LOP (MPa)	f_{R1} - CMOD 0.5 mm (MPa)	f_{R2} - CMOD 1.5 mm (MPa)	f_{R3} - CMOD 2.5 mm (MPa)	f_{R4} - CMOD 3.5 mm (MPa)
Control (IMCYC)	1	4.50	2.10	2.60	2.90	3.10
	2	4.20	1.90	2.40	2.60	2.80
	3	4.80	1.90	2.30	2.80	3.00
	CV	6.7%	5.9%	6.3%	5.5%	5.1%
	Mean	4.50	1.97	2.43	2.77	2.97

For their part, Tables 2 and 3 present results from the two experimental campaigns conducted in collaboration with UNAM for beams and cubes, respectively. These results likewise show average values that exceed the residual strength parameters used in the model iterations within the ATENA software applied to the structural design of the present project.

Table 2: Residual strength values from research tests performed at UNAM for beams

Sampling	Campaign number	LOP (MPa)	f_{R1} - CMOD 0.5 mm (MPa)	f_{R2} - CMOD 1.5 mm (MPa)	f_{R3} - CMOD 2.5 mm (MPa)	f_{R4} - CMOD 3.5 mm (MPa)
Research (UNAM)	1	3.81	2.05	2.13	2.26	2.34
	2	3.74	2.46	2.89	2.85	2.98
	CV	1.3%	12.9%	21.4%	16.3%	17.0%
	Mean	3.78	2.26	2.51	2.56	2.66

Table 3: Residual strength values from research tests performed at UNAM for cubes

Sampling	Campaign number	LOP (MPa)	f_{R1} - CMOD 0.5 mm (MPa)	f_{R2} - CMOD 1.5 mm (MPa)	f_{R3} - CMOD 2.5 mm (MPa)	f_{R4} - CMOD 3.5 mm (MPa)
Research (UNAM)	1	3.81	2.30	2.25	2.38	2.28
	2	3.01	2.46	2.56	2.81	2.87
	CV	16.6%	4.8%	9.1%	11.7%	16.2%
	Mean	3.41	2.38	2.41	2.60	2.58

Considering the aforementioned results, the research study conducted in collaboration with UNAM concludes with the following correlation equations for the proportional limit and residual strengths, expressed as a function of the loads obtained from the Montevideo test.

$$f_{LOP} = \frac{3f_{LOP}l}{2bh_{sp}^2} = 1.44 \frac{f_{LOP}^{MVD}l}{bh_{sp}^2} \quad (1)$$

$$f_{Ri} = \frac{3f_i l}{2bh_{sp}^2} = 2.47 \frac{f_{Ri}^{MVD}l}{bh_{sp}^2} \quad (2)$$

On the other hand, the average results of the evaluation of concrete shrinkage under laboratory conditions for both campaigns are presented in Fig. 5, where it is evident that the shrinkage of the concrete placed in the project at 92 days (with 480 $\mu\epsilon$ and 500 $\mu\epsilon$ respectively) is less than 600 $\mu\epsilon$ in the model iterations for the ATENA software applied to the design of the jointless floor.

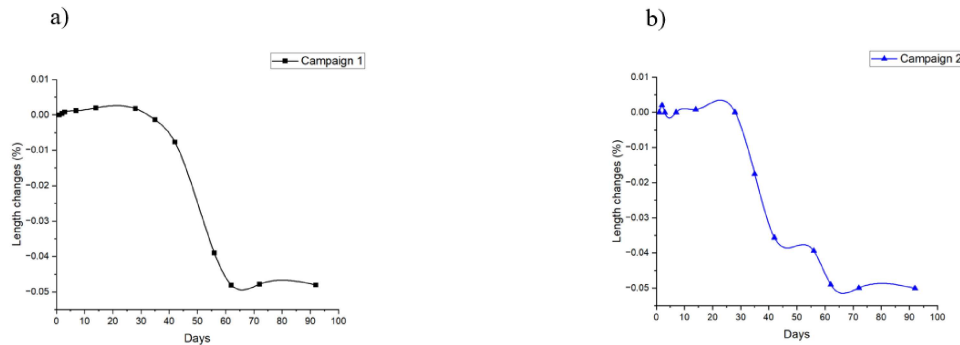


Figure 5: a) shrinkage campaign 1 and b) shrinkage campaign 2

Finally, in situ physical measurements were conducted at three months to determine the opening length of the construction joints (Fig. 6). By comparing these shrinkage measurements (as a function of both the long and short slab dimensions, with values of 250 $\mu\epsilon$) with the concrete shrinkage values determined under laboratory conditions, it was verified that the shrinkage values are evidently lower due to the restraints present at the slab joints and the friction generated between the slab and its base.

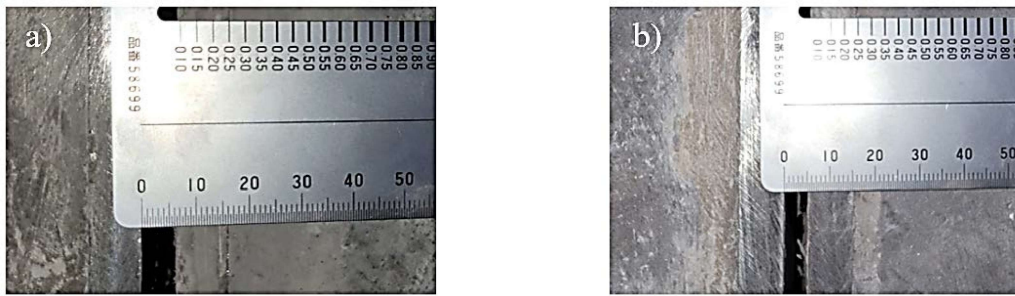


Figure 6: a) joint opening long side and b) joint opening short side

5 Concluding remarks

The design of jointless industrial floors cannot be considered a straightforward extension of conventional slab design, as it involves a significantly higher level of complexity due to the interaction of material behavior, environmental conditions, and boundary constraints. Unlike traditional structural elements, failure mechanisms in industrial floors are not always clearly defined, and serviceability criteria often govern performance.

The results presented in this study confirm that concrete shrinkage is not a single deterministic parameter but a time-dependent, environment-driven phenomenon that must be evaluated as part of a coupled system. The observed discrepancies between theoretical predictions, laboratory measurements, and field performance highlight the limitations of simplified design approaches.

In this context, a comprehensive understanding of concrete material parameters – including diffusion properties, viscoelastic response, and fiber-reinforced post-cracking behavior – is essential for reliable prediction. The study demonstrates that advanced finite element analysis (FEA) provides a suitable framework to integrate these variables and to simulate the evolution of stresses, deformations, and cracking over time.

A case study from Mexico was presented to illustrate the challenges associated with current regulatory frameworks and to evaluate the applicability of the modelling approach under real construction and environmental conditions. Furthermore, specific experimental procedures and material characterization approaches were developed to support the numerical modeling process and improve prediction accuracy.

The presented results indicate that the integration of experimental characterization and FEA-based modelling can support the assessment of jointless floor behaviour and help reduce uncertainty in design decisions. This is particularly relevant for modern industrial applications requiring high precision, such as automated logistics systems.

Further research and additional case studies are needed to establish more robust performance-based design methodologies for jointless industrial floors.

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