Proceedings of the Eighteenth International Conference on
Civil, Structural and Environmental Engineering Computing
Edited by: P. Iványi, J. Kruis and B.H.V. Topping
Civil-Comp Conferences, Volume 10, Paper 5.2
Civil-Comp Press, Edinburgh, United Kingdom, 2025
ISSN: 2753-3239, doi: 10.4203/ccc.10.5.2

Application of Artificial Intelligence in the Nondestructive Evaluation of Concrete Floors

M. Moj, S. Czarnecki and Ł. Sadowski

Department of Materials Engineering and Construction Processes, Wroclaw University of Science and Technology, Poland

Abstract

The demand for storage and industrial spaces is constantly growing. Their proper execution is crucial to ensure functional parameters. They are to ensure trouble-free use of such space over a period of 20-50 years without the need for drastic repair work. It is important to have an experienced execution team as well as to follow the instructions and recommendations of the designer and manufacturer of materials for the execution of such a surface. The next element is the evaluation of these properties that includes a series of tests of a destructive nature, which are either performed to a very limited extent or performed on a full scale cause a certain amount of damage necessary to repair even before the use of such a floor. This work is in the nature of a scientometric analysis to determine the scope of applications of non-destructive methods and artificial intelligence as a remedy for the indicated problems in the evaluation of concrete floors. Unfortunately, despite the large-scale interest in artificial intelligence in the concrete industry as well, attention is not given to nondestructive evaluation of concrete floor properties. Determination of compressive strength and crack detection based on image analysis is an insufficient approach especially in the aspect of the subsurface layer.

Keywords: concrete floors, functional properties, machine learning, artificial intelligence, non-destructive testing methods, subsurface zone.

1 Introduction

Due to the hazards caused by the way floors are used in warehouse and industrial facilities, treatments from a wide range (Table 1) are used to improve the exposed and weakened subsurface layer of the concrete floor [1][2]. For new-build facilities, up to 75% of concrete floors are made using DST technology. The technology itself is not complicated. It involves sprinkling fresh concrete with a mineral powder containing fine aggregate and hardeners. This results in an increase in the thickness of the subsurface layer (Fig. 1) and an improvement in the parameters responsible for fulfilling the function of the embedded element. However, due to the criteria and instructions for execution, there are many errors or factors that cause damage to the reinforced layer and failure to meet the assumed requirements. Most errors are related to the execution time, which is related to the setting time of the concrete that depends on many additional factors such as the properties of the mixture and weather conditions.

Table 1. Methods of strengthening the surface of industrial floors.

Method	Layer thickness	Impact on the subsurface layer
Dry shake topping (DST)	5-15 mm	Increase hardness and abrasion resistance, color option
Silicate chemical impregnation	<1 mm (penetrates to 2–15 mm)	Increased abrasion resistance, reduced fluid absorption, reduced dusting
Polymer coatings (epoxy, polyurethane resins)	2-5 mm	Resistance to abrasion, chemicals, increased durability and ease of cleaning, color or gloss options. Decreased resistance to thermal shock
cement-polymer coatings	1-3 mm 5-15 mm	Increased abrasion resistance; decorative effect.
Concrete polishing	-	High gloss, reduced dusting
„Wet on wet”	10-30 mm	Durable, abrasion-resistant surface, strong bonding of the two layers, reduced susceptibility to dusting.

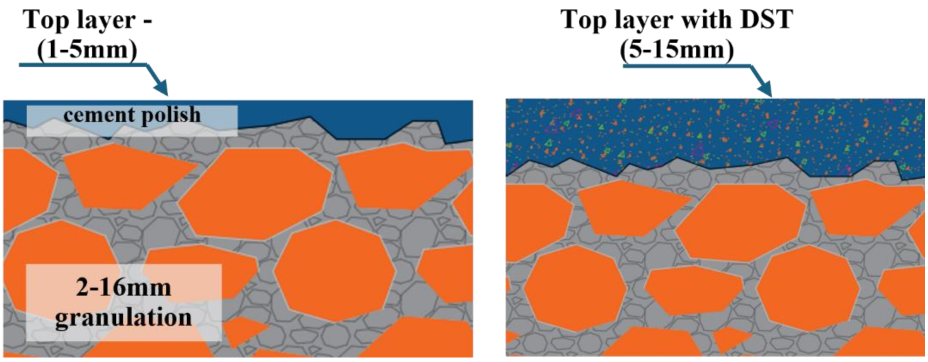

Figure 1: Section through an example of an industrial concrete floor with and without surface zone improvement with DST hardener.

Inadequate implementation, failure to eliminate harmful factors and inaccuracy in implementation can cause a number of defects such as delamination or reduced values of functional parameters [3][4]. Hence, among other reasons, the requirement for confirmation of the properties of industrial flooring before it is approved for use. Another reason for requiring evaluation is the cost aspect. The flooring in an industrial or warehouse facility can account for as much as 25% of the cost of the entire facility so adequate control is required by the investor.
Conducting tests and expert opinions analyzing the properties of floors requires the performance of damage, some of which is presented in Figure 2. The performance of an adequate and indisputable analysis requires compliance with standards Requires in the case of evaluation of pull-off strength to perform a measuring point every $3m^2$. Sampling for abrasion resistance analysis depends on the repeatability of the results, however, determining uniformity over the entire surface is not possible. Already partial tests require repairs, which is problematic in that you have to use methods different from the original technology because it is impossible to reproduce a DST floor on hardened concrete.

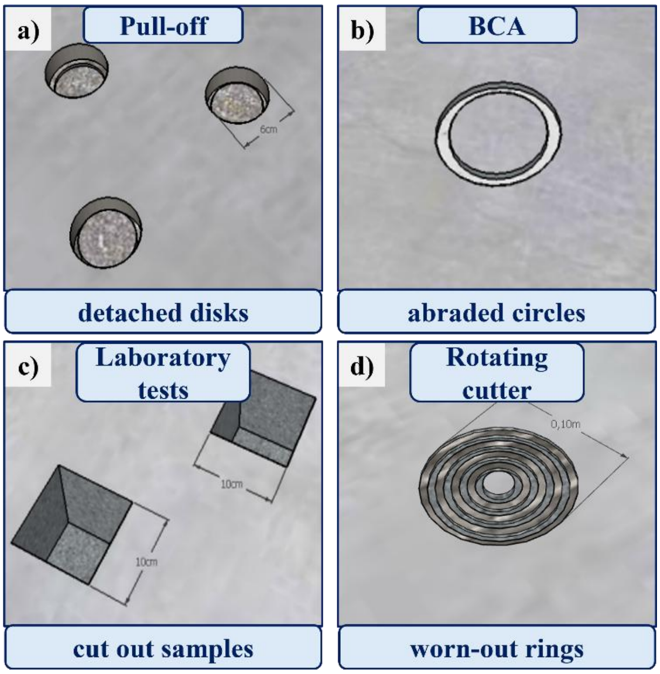

Figure 2: Damage to tested concrete surfaces.

The solution to these problems is seen in non-destructive methods [5]. They will certainly not allow the full elimination of destructive methods from the evaluation process, however, they contribute to their certain reduction. This is already happening in the case of compressive strength analysis, however, it is still insufficient accuracy of evaluation compared to the classical path of analysis. Researchers often suggest a combinatorial approach as a way to increase the accuracy of the evaluation [6][7], however, even this solution is often insufficient. Artificial intelligence is revealing itself as a solution, one of the advantages of which is the ability to increase the accuracy of mathematical models [8]. Despite the significant increase in popularity of this solution in recent times, in the subject of nondestructive evaluation of concrete floors, not many works on this subject can be found. The only thriving section related, so to speak, to the surface of concrete floors nondestructively tested with the support of artificial intelligence is to assess the quality [9] and the detection and classification of concrete surface cracks based on image analysis [10][11].

2 Methodology

In order to determine the involvement of the scientific community in the range of issues described in the introduction, the Scopus database was analyzed. The procedure is specified in Figure 3. It was decided to search the database for the keywords: concrete floor and artificial intelligence or machine learning and concrete floor and nondestructive tests. Any attempt to limit or combine the keywords or to specify the issue such as limiting to functional parameters or the subsurface zone ended the search with less than 20 papers. Such small databases do not allow one to determine the trend and potential links thereby determining the direction of future research in the analysis of concrete floor subsurface parameters towards NDT+AI. After reviewing the search results, a qualitative assessment of the relevance of publications with the presented topic was made. The obtained results were analyzed in the VOSviewer program to determine the network of links by excluding from the analysis the keywords on the basis of which these articles and their derivatives were selected. Due to the impossibility of direct linking of concrete floor AI or ML and NDT passwords, the review was carried out separately for issues related to artificial intelligence and separately for issues related to nondestructive methods. The search was conducted on 04.04.2024.

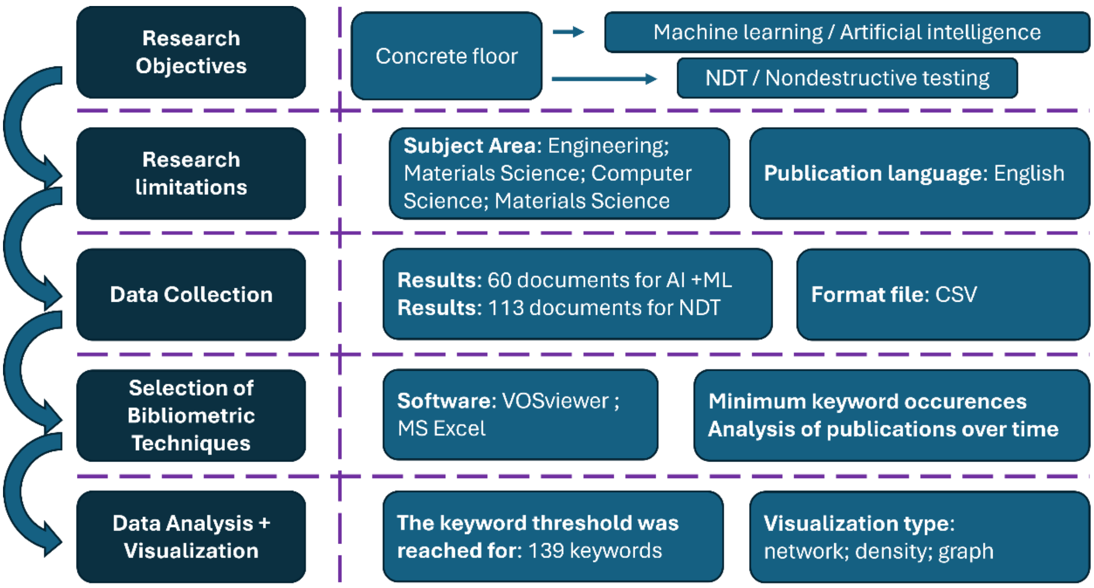

Figure 3: The process of literature analysis on bibliographic data.

3 Results

First, the interest in the use of AI and NDT methods in the evaluation of concrete floors was analyzed separately. The juxtaposition according to the number of publications in a given area up to a given year is illustrated in Figure 4. While the movement in the use of AI is also developing dynamically in concrete floors, in the case of the use of NDT methods it is rather stagnant probably due to the slower development of new available techniques in this area and the known methods do not contribute additional information. One even gets the impression that the rapid increase in interest in AI in 2021 may have been caused by a desire to fill the void of declining interest in NDT methods. To determine the complete picture, a linkage map was made for both databases, which are presented in Figure 5 and Figure 6.

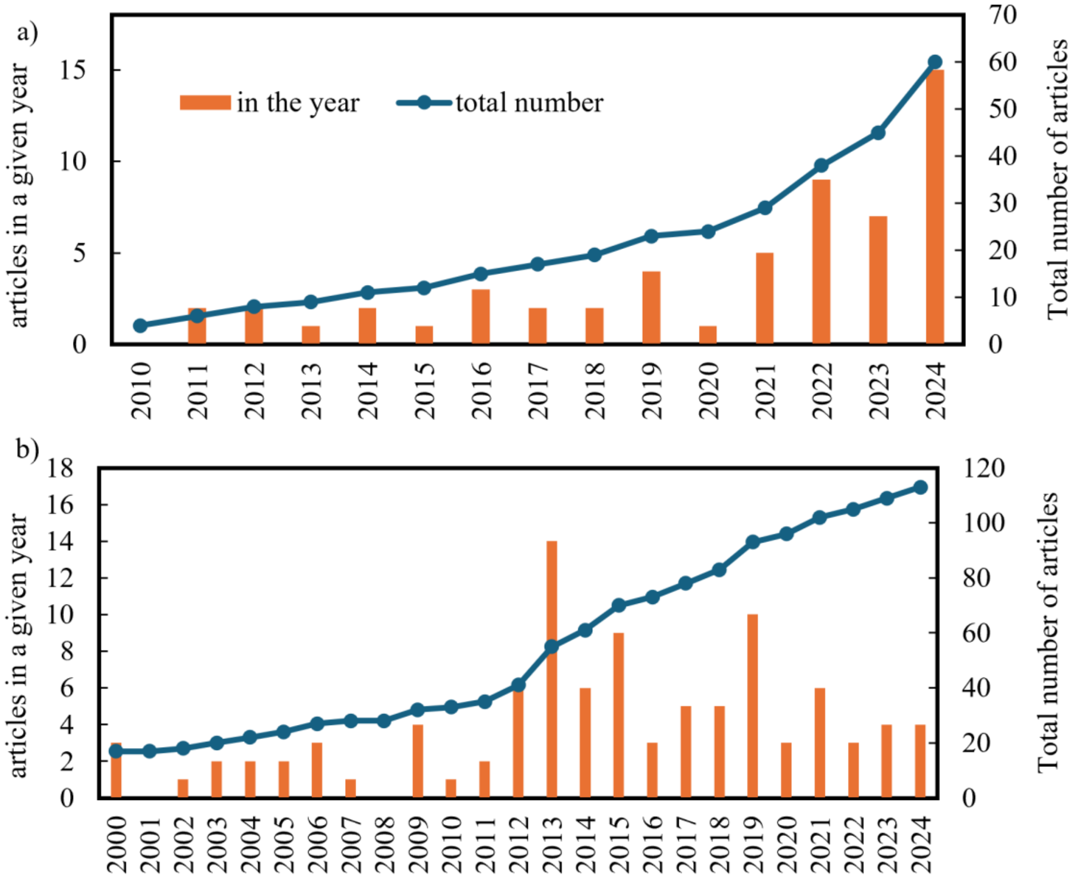

Figure 4: Interest in using artificial intelligence or machine learning (a) and nondestructive methods (b) with concrete floor based on Scopus.

According to the methodology, connection and density network maps were developed for the range of artificial intelligence applications for concrete floors (Fig.5). In order to more accurately assess the range of applications and interests related to the subject matter, the words artificial intelligence, machine learning, concrete floors and phrases similar to those shown were removed from the analysis. Due to the small base of works, the importance of connections between phrases, determined by the thickness of the line connecting the phrases, is almost imperceptible. The related topics can be divided into five categories and are: architecture and design; geology and geotechnics; concrete properties; machine learning algorithms; and concrete surface properties. All of the topics are linked to different prediction models. Noteworthy are only 2 prominent properties of concrete elements defined by compressive strength and surface roughness. This is directly reflected in the publications, most of which are concerned with the prediction of compressive strength while roughness is often used as an input parameter, e.g. for adhesion evaluation.

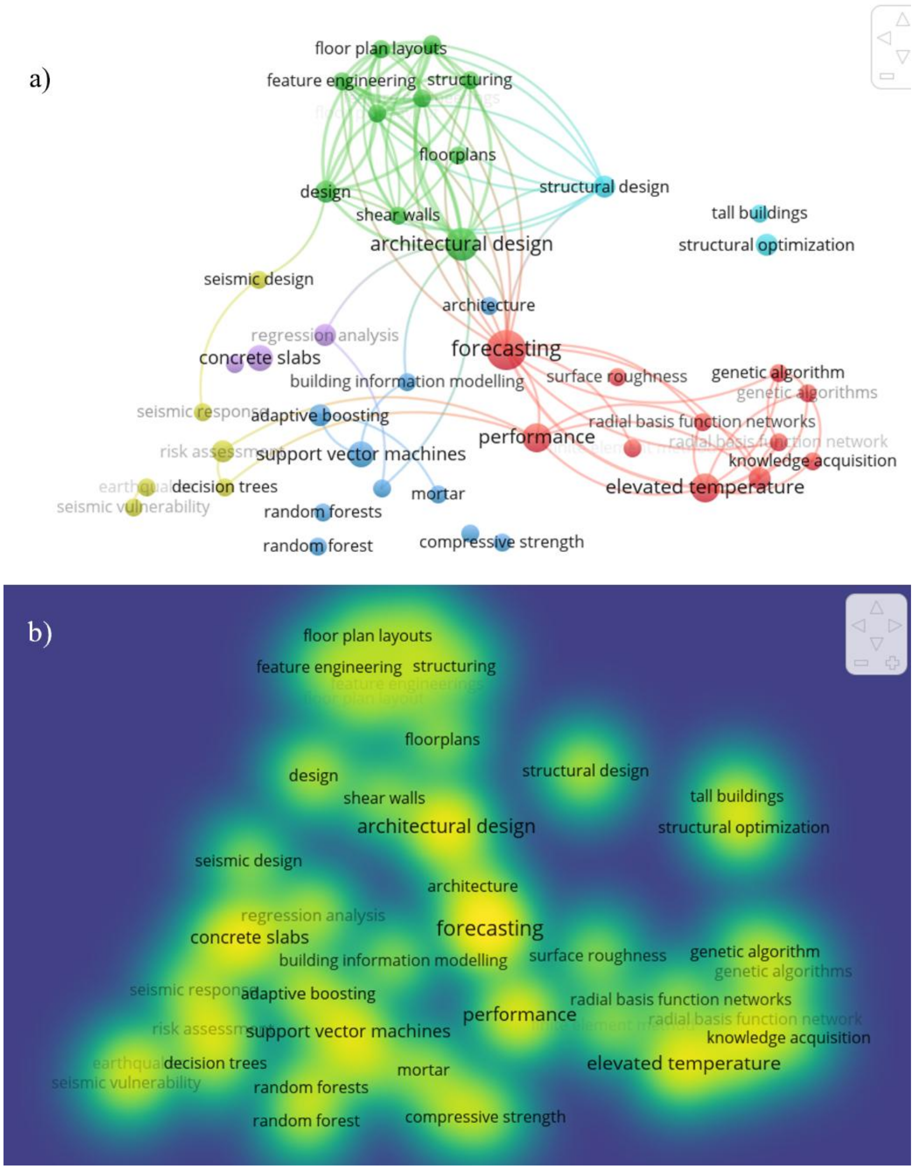

Figure 5: Results of scientometric analysis on network visualisation (a) and density visualisation (b) for the base of the use of AI in the concrete flooring field.

A review of a database containing a collection of publications on the application of nondestructive methods to concrete floors (Fig.6). Due to the almost double size of the database resource, one can already see the varying thickness of the network connections. There were 4 main areas around the topics connecting under the keyword nondestructive evaluation of industrial floors. The red area was identified under the phrase structural condition monitoring, the green color relates to damage and crack assessment. The blue color is related to repairs while the yellow color was identified as buzzwords related to AI approaches. In all the main buzzwords one can find various nondestructive evaluation techniques mainly related to acoustic and sclerometric methods. The visualization of the densities indicates that the interest in AI in this matter is strong while the range of connections suggests that this is being treated selectively at this stage.

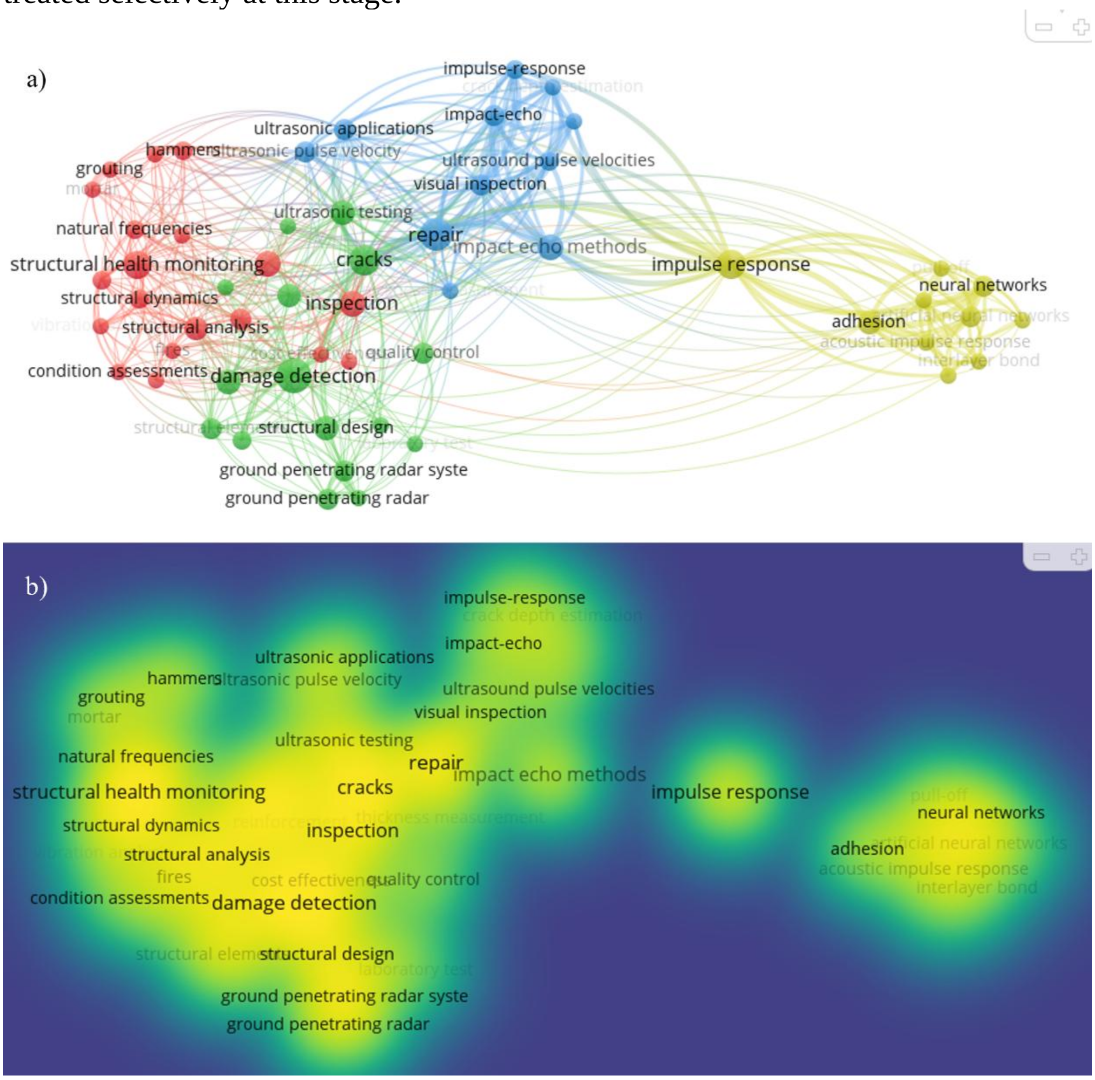

Figure 6: Results of scientometric analysis on network visualisation (a) and density visualisation (b) for the base of the use of NDT in the concrete flooring field.

4 Conclusions

The paper analyzed scientific publications thematically related to the use of NDT methods and artificial intelligence in the evaluation of concrete floor properties. A survey of the literature showed that a comprehensive approach to supporting NDT methods with AI analysis is not being developed. Considering a number of advantages of the novel approach confirmed specifically in the case of compressive strength determination, e.g., by supporting with predictive models the SonReb approach [12] and analyses of concrete subsurface zone parameters [8] suggests success for the proposed approach to nondestructive evaluation of functional properties. After bibliographic analysis, the following conclusions were determined:

Acoustic and sclerometric methods are most commonly used in the nondestructive evaluation of concrete floors. Particularly desirable are methods that allow the element to be tested unilaterally.

The predictive models used for nondestructive analysis of concrete elements like beams and walls can be tested on floors after appropriate calibration for a method that changes the properties of the floor surface.

Available models based on artificial neural network algorithms, random forests, decision trees, suport vector machine and related ones can provide sufficient prediction accuracy for construction sector issues.

Key information in the case of flooring can be provided by assessing surface roughness and changes in temperature distribution, particularly when analyzing abrasion resistance or testing adhesion between floor layers.

In conclusion, the issue of nondestructive assessment of functional properties using artificial intelligence should greatly assist the warehouse, industrial and commercial sectors in the accurate and early detection of defects in the subsurface zone of concrete floors without the need to destroy and repair the completed elements. Existing tools and as-yet-unrecognized testing methods may allow correlation of the results of various nondestructive tests with the parameters responsible for fulfilling the function of an industrial floor. The development of a suitable database for a predictive model can significantly speed up the evaluation process and reduce to an absolute minimum the need to use destructive methods.

Funding

Authors received funding from the National Science Centre, Poland under project PRELUDIUM 23 number 2024/53/N/ST8/00451.

References

[1] B. Stawiski and Ł. Radzik, "Need to Identify Parameters of Concrete in the Weakest Zone of the Industrial Floor," in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Nov. 2017. doi: 10.1088/1757-899X/245/2/022063.

[2] N. J. B. Idrus, "Construction related factors influencing the choice of concrete floor systems," *Construction Management and Economics*, vol. 20, no. 1, pp. 13–19, Jan. 2002, doi: 10.1080/01446190110101218.

[3] J. Szymanowski, "Evaluation of the adhesion between overlays and substrates in concrete floors: Literature survey, recent non-destructive and semi-

destructive testing methods, and research gaps," *Buildings*, vol. 9, no. 9, p. 203, 2019.
[4] J. Hola, L. Sadowski, and K. Schabowicz, "Nondestructive identification of delaminations in concrete floor toppings with acoustic methods," *Autom Constr*, vol. 20, no. 7, pp. 799–807, Nov. 2011, doi: 10.1016/J.AUTCON.2011.02.002.
[5] D. Caballol, Á. P. Raposo, and F. Gil-Carrillo, "Non-destructive testing of concrete layer adhesion by means of vibration measurement," *Constr Build Mater*, vol. 411, p. 134548, Jan. 2024, doi: 10.1016/J.CONBUILDMAT.2023.134548.
[6] L. Capozzoli and E. Rizzo, "Combined NDT techniques in civil engineering applications: Laboratory and real test," *Constr Build Mater*, vol. 154, pp. 1139–1150, Nov. 2017, doi: 10.1016/J.CONBUILDMAT.2017.07.147.
[7] A. Meza, J. A. Ortiz, L. Peralta, and C. Sánchez, "Comparison between destructive and nondestructive tests in the evaluation of abrasion resistance of concrete," *J Test Eval*, vol. 46, no. 3, pp. 906–912, 2018.
[8] M. Moj and S. Czarnecki, "Comparative analysis of selected machine learning techniques for predicting the pull-off strength of the surface layer of eco-friendly concrete," *Advances in Engineering Software*, vol. 195, p. 103710, Sep. 2024, doi: 10.1016/J.ADVENGSOFT.2024.103710.
[9] Z. Xiao, Z. Liu, X. Guo, and J. Liu, "An intelligent non-destructive method to identify the quality of self-compacting concrete based on convolutional neural networks via image recognition," *Case Studies in Construction Materials*, vol. 22, p. e04442, Jul. 2025, doi: 10.1016/J.CSCM.2025.E04442.
[10] S. Chen, G. Fan, J. Li, and H. Hao, "Automatic complex concrete crack detection and quantification based on point clouds and deep learning," *Eng Struct*, vol. 327, p. 119635, Mar. 2025, doi: 10.1016/J.ENGSTRUCT.2025.119635.
[11] G. Lemaire, G. Escadeillas, and E. Ringot, "Evaluating concrete surfaces using an image analysis process," *Constr Build Mater*, vol. 19, no. 8, pp. 604–611, Oct. 2005, doi: 10.1016/J.CONBUILDMAT.2005.01.025.
[12] S. A. Alavi and M. Noel, "Effect of model architecture and input parameters to improve performance of artificial intelligence models for estimating concrete strength using SonReb," *Eng Struct*, vol. 323, p. 119285, Jan. 2025, doi: 10.1016/J.ENGSTRUCT.2024.119285.