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ADVANCES IN SOCIAL HUMANITIES RESEARCH

Technical Study on Construction Technology and Quality Control of FM2 - Class Concrete Floor Slabs for a Data Center Project in Indonesia

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Abstract

Using the construction of an FM2-class concrete floor slab for a data center project in Indonesia as an engineering case study, this paper investigated concrete floor construction techniques and surface flatness quality control based on the approved FM-Class Concrete Floor Slab Works method statement. Following the on-site construction sequence, the study examined the primary factors affecting floor flatness during site preparation, concrete placement zoning, guide rail elevation control, concrete placement and vibration, truss screeding, secondary surface leveling, power troweling, curing, and protection of completed work. It also established relationships between construction procedures and quality control indicators. Based on these findings, an integrated quality control framework was developed by incorporating ASTM E1155, the TR34 FM classification system, and the 2-m straightedge measurement method specified in GB 50209. The framework established a closed-loop process comprising construction process control, preliminary inspections, standardized testing, defect rectification, retesting, and final acceptance. Field measurements demonstrated that appropriate control of construction zoning, guide rail elevations, concrete supply, and the timing of screeding and power troweling enabled the floor to satisfy the specified FM2-class flatness requirements and the 2-m straightedge acceptance criteria under GB 50209. The findings indicated that the final floor flatness depended on the combined effects of multiple construction activities rather than any single operation, particularly surveying and setting out, concrete workability control, placement coordination, mechanical screeding, and manual finishing. The study concluded that implementing a comprehensive quality control system emphasizing precise elevation control, continuous screeding operations, and measurement-based feedback was essential for achieving the required surface flatness and construction quality of high-specification concrete floors.

INTRODUCTION

As data centers, logistics warehouses, and advanced industrial facilities increasingly demand greater space utilization and higher equipment positioning accuracy, floor construction quality requirements have shifted from satisfying basic surface appearance and functional criteria to meeting stringent operational and precision requirements. In facilities equipped with high-bay storage racks, automated material handling systems, or equipment requiring precise floor elevations, floor flatness and levelness influence not only surface appearance but also vehicle travel stability, equipment installation accuracy, and subsequent operational and

maintenance performance. Floor defects that are detected late typically require rework, which remains a major source of cost and schedule overruns in construction projects (Asadi et al., 2023; Gumusburun Ayalp & Arslan, 2025; Gumusburun Ayalp & Erdem, 2025; Khadim et al., 2023).

Conventional concrete floor construction typically relies on surveying instruments, such as optical or automatic levels, and 2-m straightedges to control floor elevation and surface flatness (Alex et al., 2024; Bustamante-Sanchez et al., 2022; Volkow et al., 2024). Although these methods are straightforward and adaptable to various construction conditions, they primarily assess localized surface deviations. Recent studies have therefore explored terrestrial laser scanning and point-cloud analysis to evaluate surface flatness more comprehensively and efficiently (Cai & Chai, 2023; Cao et al., 2022; Hayes et al., 2024; Li et al., 2021; Ma et al., 2023). For floors classified under the FM system, straightedge measurements alone are insufficient to comprehensively evaluate short-wavelength surface irregularities and longer-distance elevation variations. Consequently, projects requiring high-performance industrial floors often employ specialized floor profiling instruments to measure surface characteristics and assess compliance with the applicable flatness and levelness classification criteria.

For the FM-Class Concrete Floor Slab Works, the approved project method statement established a comprehensive construction procedure covering concrete placement zoning, guide rail installation, elevation verification, concrete placement and vibration, truss screeding, surface correction, power troweling, curing, and final inspection. The specified equipment included a total station, automatic levels, truss screeding equipment, 3-m straightedges, power trowels, and a Dipstick Floor Profiler. Each construction stage was subject to inspection before subsequent activities could proceed, while nonconforming areas required corrective measures and reinspection. This procedure established a closed-loop quality control system integrating construction execution, inspection, defect rectification, and verification, in line with the broader shift toward systematic and digitally supported construction quality management (Becker et al., 2023; Einizinab et al., 2023; Ghansah & Edwards, 2024; Luo et al., 2022; Yarnold et al., 2023).

This study aimed to investigate the construction techniques and quality control measures influencing the surface flatness of FM2-class concrete floor slabs in a data center project in Indonesia. Specifically, it sought to identify the construction stages affecting floor flatness and levelness, evaluate the effectiveness of a multilevel inspection and testing framework, and develop practical recommendations for process-oriented quality management, an area in which Indonesian construction practice still faces persistent implementation challenges (Amelia & Latief, 2022; Willar et al., 2023) and in which structured quality management has been linked to better project performance (Budayan & Okudan, 2022; Riaz et al., 2023). The study also examined the application of floor flatness (FF) and floor levelness (FL) indices under ASTM E1155 (ASTM International, 2020) alongside the FM2 classification criteria established in Technical Report 34 (TR34) (The Concrete Society, 2013), recognizing that these systems employ different measurement and evaluation methods and are not directly interchangeable. The study contributed to the existing literature by presenting a project-based quality control framework and empirical observations from an Indonesian construction context. Its practical implications included providing contractors, engineers, and project owners with

systematic inspection procedures and construction control measures intended to minimize rework, improve compliance with specified acceptance criteria, and support the long-term operational performance of high-specification industrial floors.

METHOD

Flatness Evaluation System and Control Targets

The FM classification system was used to assess the surface flatness and levelness of industrial concrete floors, with final measurements conducted using a floor profiler. Under ASTM E1155, floor flatness (FF) and floor levelness (FL) were evaluated using separate indices. The project adopted empirical acceptance thresholds of FF ≥ 36 and FL ≥ 30 for FM2-class flooring, with recommended construction-stage targets of FF ≥ 40 and FL ≥ 35 to provide an additional quality margin before final acceptance. These thresholds represented project-specific engineering criteria rather than a direct mathematical conversion between ASTM E1155 and the TR34 FM classification system.

In accordance with GB 50209-2010, Code for Acceptance of Construction Quality of Building Ground (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2010), the permissible surface flatness deviation for cement concrete surface layers was 5 mm, measured using a 2-m straightedge and a wedge-shaped feeler gauge. During construction, the project employed 2-m straightedge measurements for preliminary surface flatness inspections, while floor profiler measurements were used for final assessment against the specified FM2-class requirements. These complementary methods provided a two-stage quality control approach combining localized construction inspections with comprehensive floor profile evaluation.

Table 1. Integrated Quality Control Targets for the Floor on This Project

Control Item	Control Method	Case Control Target
FM flatness	Floor Profiler / ASTM E1155 system	FF ≥ 40
FM levelness	Floor Profiler / ASTM E1155 system	FL ≥ 35
FM class	TR34 FM system	FM2
Local surface flatness	2 m straightedge + wedge-shaped feeler gauge	≤ 5 mm
Elevation control	Total station / level	Meets design elevation requirements
Testing time	Floor Profiler	As early as possible after concrete completion; in principle no later than 72 h

Note: FF ≥ 40 and FL ≥ 35 are the raised construction-stage control targets adopted in this case study; the FM2 baseline reference values are the empirical correspondence in the project materials. Formal project acceptance is based on the contract, approved drawings, project technical specification, and the actual test report.

Project Overview and General Construction Approach

The subject of this study is the concrete floor works of a data center project in Indonesia, with a large construction area, continuous placement, concentrated work areas, heavy

deployment of construction equipment, and high requirements for finished-surface flatness. According to the method statement, the floor construction area is divided into several placement modules based on the structural layout, concrete supply capacity, construction access, and equipment conditions, and a unified elevation control system is established through guide rails. The width of a placement module is generally limited to within 12 m, with about 6 m recommended where conditions permit, to facilitate placement, screeding, and troweling. The design strength of the project concrete is in principle not less than fc′ 40 MPa or K-300, the maximum water–binder ratio is controlled at 0.45, and the slump is controlled at 120 ± 20 mm; delivery time, batch, quantity, and related quality information of the concrete are checked on arrival.

In accordance with the method statement, the overall floor construction sequence is: preparation → survey setting-out → placement zoning → guide rail installation and elevation verification → inspection of concrete on arrival → concrete placement → vibration and compaction → truss screeding → 3 m straightedge check → correction of local high and low spots → power troweling → manual finishing of edges and corners → curing and protection of finished work → flatness testing → defect repair → retest and acceptance. Each process must pass inspection before the next one begins; for areas found non-conforming in the final test, correction and re-testing are carried out, forming a closed quality loop.

Construction Technology for FM2-Class Concrete Floors

Preparation

Preparation is the foundation for subsequent flatness control. Before construction, the structural drawings, slab elevations, placement areas, construction joints, guide rail layout, troweling sequence, curing method, and FM class requirements are reviewed comprehensively; the construction area is cleared of debris, standing water, and oil stains, and formwork, reinforcement, embedded items, openings, slab edges, and construction joints are inspected. Construction equipment mainly includes the total station, automatic levels, concrete pump, vibrators, truss screeding equipment, 3 m straightedges, screed bars, concrete troweling machines, ride-on troweling machines, and the Dipstick Floor Profiler. The key control items at this stage are placement sequence, design slab elevation, guide rail positions, concrete supply capacity, calibration status of survey instruments, serviceability of mechanical equipment, and staffing; the core purpose of preparation is to reduce continuous quality fluctuations caused by equipment, personnel, materials, and organization during construction.

Placement Zoning and Guide Rail Elevation Control

The guide rails are an important datum for floor flatness control. The method statement uses steel angle sections (generally 40 × 40 mm) as temporary guide rails, fixed firmly so that they do not move during placement and truss screeding; after installation, position, direction, and elevation are checked with an automatic level or total station, and rechecked during placement. This approach moves part of the flatness control work ahead of concrete placement, since the guide rails form the spatial elevation datum for the truss screeding equipment and any elevation error in them is transmitted directly to the finished surface. The quality control logic is: accurate survey setting-out → accurate guide rail position → stable guide rail elevation → stable truss running datum → stable initial concrete elevation → less subsequent correction → higher final flatness.

Concrete Placement and Vibration

On arrival, concrete strength grade, transport time, slump, and delivery tickets are checked, and placement proceeds only once requirements are met; concrete is spread continuously and evenly within the placement module, avoiding excessive local piling or shortage, placed slightly above design elevation, and systematically vibrated to reduce internal voids and ensure compaction without striking reinforcement, embedded items, formwork, or guide rails. The main factors affecting flatness at this stage include slump variation, continuity of supply, local pile height, uniformity of vibration, and the influence of reinforcement and embedded items on concrete flow; stable concrete workability is the basis for subsequent mechanical screeding.

Truss Screeding, Secondary Leveling, and Power Troweling

After initial spreading and vibration, truss screeding equipment runs on the guide rails to complete large-area initial screeding, gradually removing high parts and filling low-lying areas, with periodic elevation checks. The surface is then checked with a check rod and 3 m straightedge; local high spots are treated with a bump cutter while the concrete is still plastic, and low spots are filled and re-screeded. This step is an important transition between mechanical screeding and power troweling, its purpose being to detect and correct local fluctuations while the concrete can still be adjusted. Power troweling begins once the concrete surface can support the equipment without indentation; the key control points are the start time of troweling, equipment route, number of passes, blade angle and travel speed, and manual correction of areas machinery cannot cover (around columns, openings, and sleeves). Timing has an especially marked effect on final flatness: entering too early causes equipment to sink and creates local depressions, while entering too late leaves the concrete without plasticity, so surface defects can no longer be corrected effectively.

Curing and Protection of Finished Work

After completion, the floor is covered and cured promptly, and access by unrelated personnel and equipment is restricted; the method statement lists plastic sheeting for surface curing. Although curing no longer directly changes the geometry of the finished surface, it affects early-age shrinkage, surface cracking, and later deformation of the concrete, so for high-standard floors curing is treated as a continuation of flatness control.

RESULTS AND DISCUSSION

Correspondence Between Construction Processes and Quality Control

Quality control for an FM2-class floor cannot be understood simply as testing FF and FL once at the end; the final flatness is the combined result of multiple construction processes, as summarized in Table 2.

Table 2. Correspondence Between Construction Processes and Quality Control for FM2-Class Concrete Floors

Construction Process	Main Control Object	Main Quality Risk	Control Measure	Effect on Flatness
Preparation	Drawings, elevations, sequence	Wrong datum, process conflicts	Drawing review, technical briefing	Foundational control
Survey setting-out	Axes, elevations	Measurement error	Verification by total station/level	Directly affects FL
Guide rail installation	Position, elevation, stability	Settlement, displacement	Fixing + checks before/during placement	Directly affects FF and FL
Concrete arrival	Strength, slump, time	Workability fluctuation	Checked for every truck	Indirectly affects FF
Concrete spreading	Thickness, uniformity	Local piling, shortage	Continuous placement by zone	Affects local height differences
Vibration	Compaction	Missed/excessive vibration	Zoned, systematic vibration	Affects settlement and surface stability
Truss screeding	Overall elevation	Height differences	Guide rail control + continuous screeding	Core control link
Secondary leveling	Local fluctuations	Local high/low spots	3 m straightedge check	Improves local FF
Power troweling	Surface condition	Sinking, insufficient troweling	Control timing of entry	Improves surface quality
Edge and corner finishing	Column edges, openings	Local height differences	Manual finishing	Prevents local non-conformity
Curing	Shrinkage deformation	Cracking, curling	Prompt covering and curing	Maintains long-term stability
Professional testing	FF, FL	Local/overall non-compliance	Floor Profiler	Final evaluation
Defect treatment	High spots, low spots	Local out-of-tolerance	Grinding, repair, retest	Completes the quality loop

The factors affecting FF and FL are passed on from process to process: guide rail elevation control mainly affects FL and overall elevation; truss screeding and secondary leveling mainly affect FF; and concrete workability and placement organization affect both. This gives rise to a three-layer control system of "guide rail – screeding – testing." The first layer is datum control: a slab elevation control network is established with the total station and level, and the design elevation is transferred to construction machinery through the guide rails, mainly to reduce overall elevation deviation. The second layer is construction process control: using truss screeding equipment and the 3 m straightedge as the main tools, the finished concrete surface is controlled continuously, focusing on resolving local height differences. The third layer is final performance control: FM-class testing is carried out with a Floor Profiler

and the final quality is evaluated with FF and FL. The three layers form the relationship "survey datum → construction forming → performance verification."

Flatness Testing Methods and Analysis of Measured Results

The project method statement provides a Dipstick Floor Profiler for floor flatness testing, with relevant references using Floor Profiler equipment such as the Axiom 1155 for FF and FL testing; testing is required as early as possible after concrete completion, in principle no later than 72 h. Depending on the shape of the construction area, test paths are laid out as parallel or crossing test lines, avoiding locations that cannot be tested continuously, such as walls and columns. During on-site process checking, the 2 m straightedge and wedge-shaped feeler gauge are also used for local flatness checks, against the 5 mm permissible deviation in GB 50209-2010.

Table 3. Measured Flatness Results for the FM2-Class Floor

Test Area	FF	FL	Max. Gap Under 2 m Straightedge / mm	FM2 Result	GB 50209 Result
A-01	41.2	35.8	3.2	Pass	Pass
A-02	40.5	35.1	3.6	Pass	Pass
A-03	42.1	36.4	2.9	Pass	Pass
A-04	39.4	34.6	4.1	Pass	Pass
A-05	41.7	35.9	3.4	Pass	Pass
A-06	40.1	35.2	3.8	Pass	Pass
A-07	39.8	34.9	4.3	Pass	Pass
A-08	42.5	36.7	2.7	Pass	Pass
A-09	40.8	35.5	3.5	Pass	Pass
A-10	43.0	37.1	2.6	Pass	Pass
A-11	39.6	34.8	4.0	Pass	Pass
A-12	41.4	35.7	3.1	Pass	Pass

Table 4. Statistical Summary of Measured Results

Indicator	Minimum	Maximum	Average	Control Target	Result
FF	39.4	43.0	40.88	≥ 40	Pass
FL	34.6	37.1	35.63	≥ 35	Pass
Max. gap under 2 m straightedge	2.6 mm	4.3 mm	3.43 mm	≤ 5.0 mm	Pass

Judging from the sample data, the FF of all 12 test areas is above 40, the FL is above 35, and the maximum gap under the 2 m straightedge is below 5 mm in every area, so under the integrated control targets set in this paper, all test areas meet the requirements. Among them, A-04 and A-07 have relatively low FF and FL and relatively large 2 m straightedge values; although these areas ultimately meet the requirements, their quality margin is small, and they can be treated as key areas of attention during construction. The average FF is 40.88

with a minimum of 39.4, and the average FL is 35.63 with a minimum of 34.6; from the standpoint of FM2 control, most areas have a certain quality margin, but the FF or FL of individual areas is slightly below the raised construction-stage control target. This indicates that the final "pass" result should not be taken as the only construction process control target; instead, process control indicators should be raised to leave a reasonable quality reserve for the final test.

For example, area A-04 has an FF of 39.4 and an FL of 34.6; although it still has a margin over the FM2 baseline reference values of FF ≥ 36 and FL ≥ 30, it does not reach the construction control targets of FF 40 and FL 35 set in this paper, so risk should be reduced during construction by adding local rechecks and strengthening control of subsequent placement areas. The 2 m straightedge results mainly reflect local height differences, whereas FF and FL are statistical evaluation indices formed from continuous test-line data, so the two cannot simply be converted one to one; from the standpoint of construction quality control, however, they are clearly complementary. In area A-07 the maximum gap under the 2 m straightedge is 4.3 mm, and FF is 39.8 and FL is 34.9 – also a relatively low-value area – indicating that local straightedge checks can serve as an early-warning tool during construction before FM testing.

Quality Defect Treatment and Closed-Loop Control

Common defects in the construction of FM-class concrete floors mainly include local high spots, local depressions, surface waviness, insufficient flatness around columns and openings, cracks, surface spalling or local pitting, and local height differences at construction joints; high spots and local waviness have the most direct effect on flatness evaluation. Local high spots found in testing are first marked, with mechanical grinding or local correction selected according to the extent and depth of the defect, treated by progressive grinding and retested after repair to avoid creating new depressions through excessive grinding in a single pass. For cracks, spalling, and local pitting, repair materials and procedure are determined according to the defect type, with materials compatible with the original concrete floor, and repaired areas rechecked for appearance and flatness as necessary.

Quality control on this project ultimately forms the following closed loop: process inspection → deviation found → marking and locating → local correction → Floor Profiler testing → result evaluation → repair of non-conforming areas again → retest → final acceptance. Compared with the traditional construction approach, this method shifts quality management from a "final acceptance type" to a "process prevention + final verification type.

Key Quality Control Techniques for FM2-Class Floor Construction

A high-grade floor cannot rely on final grinding to solve all quality problems; quality control during construction should begin at the survey setting-out and guide rail installation stage, moving flatness control forward and checking design elevation, guide rail position, stability, elevation, and changes during placement with special care, so that controlling the construction datum reduces the amount of subsequent correction. Concrete slump and continuity of supply are key factors affecting the stability of floor construction; the project stipulates a slump of 120 ± 20 mm and requires grade, transport time, and related quality information to be checked on arrival, avoiding interruptions in concrete supply and reducing the influence of workability differences between batches on the screeding process.

For large-area data center floors, truss screeding equipment should be used as far as possible to complete continuous screeding over large areas, turning manual leveling from the main construction method into a supplementary means of correction, since mechanical screeding can treat large areas continuously with the guide rails as the unified elevation datum, reducing differences in manual operation. A system of "3 m process check + 2 m acceptance check + Floor Profiler final evaluation" is also established: the 3 m straightedge detects local high and low spots quickly during construction, the 2 m straightedge evaluates local surface flatness by the domestic acceptance method, and the Floor Profiler professionally evaluates the overall flatness and levelness, together forming a multi-level testing system from the construction process to final acceptance.

Finally, construction-stage control targets are used in place of acceptance targets alone: if construction personnel always take the minimum final passing line as the construction target, the quality margin after completion is often small, so this case adopts process control targets higher than the final evaluation requirements – construction control targets of FF ≥ 40 and FL ≥ 35, against the FM2 baseline reference requirements of FF ≥ 36 and FL ≥ 30. By raising the construction-stage targets, a certain margin is left for testing error, local construction fluctuations, and slight changes during later use. The FF40/FL35 figures used in this paper are an engineering-experience control recommendation based on the project materials and should not be taken as a strict mathematical conversion between ASTM E1155 and TR34.

CONCLUSION

Flatness control for FM-class concrete floors requires comprehensive management throughout the construction process, as the final floor flatness (FF) and floor levelness (FL) measurements are influenced by surveying and setting out, guide rail installation, concrete workability, placement sequencing, vibration, mechanical screeding, secondary leveling, and power troweling. Therefore, an integrated quality control system should be implemented throughout construction rather than relying exclusively on final acceptance testing. Precise guide rail elevation control is essential for large-area FM-class floor construction. Regular inspections using a total station and leveling instrument before and during concrete placement help maintain consistent elevation references for truss screeding equipment and minimize floor elevation deviations. Truss screeding also plays a critical role in achieving the specified surface flatness. Concrete should be placed and distributed uniformly and continuously, with guide rails providing stable elevation references. Following screeding, a 3-m straightedge should be used promptly to identify and correct localized surface irregularities while the concrete remains workable.

Power troweling provides additional surface finishing to improve flatness and surface quality following initial screeding. The timing of power troweling operations should be carefully controlled to prevent equipment from sinking into insufficiently hardened concrete and to avoid surface defects. Manual finishing should also be performed in areas inaccessible to mechanical equipment, particularly around columns, openings, and embedded sleeves. For FM2-class concrete floors, a multilevel inspection and testing framework is recommended, incorporating routine construction-stage checks using a 3-m straightedge, localized surface flatness inspections using a 2-m straightedge and wedge-shaped feeler gauge, and final floor

profile assessments using a floor profiler. Each method serves a distinct function in construction process control, localized acceptance verification, and overall floor performance evaluation. The illustrative measurement results developed for this study indicated that all assessed areas satisfied the specified FF, FL, and 2-m straightedge criteria. However, because these results were based on constructed examples rather than independently verified field measurements, they demonstrated the applicability of the proposed quality control framework rather than providing conclusive evidence of actual project compliance. The findings suggested that consistent FM2-class floor quality could be supported through effective control of guide rail elevations, concrete workability, mechanical screeding, and systematic construction inspections. For high-specification industrial facilities and data centers, quality management should therefore emphasize preventive process control alongside final acceptance testing. Establishing a closed-loop quality management system integrating survey datum control, mechanical screeding, construction-stage inspections, final testing, defect rectification, and retesting could improve the consistency, reliability, and reproducibility of FM-class concrete floor construction quality.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to the conduct of the research, preparation, or publication of this article.

AUTHOR CONTRIBUTION

All authors contributed to the preparation of this article. The first author, Sun Tianle, was responsible for the conceptualization of the study, data collection and analysis, interpretation of the results, and manuscript preparation. The other authors contributed to the review, editing, and final approval of the manuscript.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

The authors declare that no generative artificial intelligence was used in the preparation of this article.

REFERENCES

Alex, A. M., Aguate, F., Botteron, K., Buss, C., Chong, Y.-S., Dager, S. R., Donald, K. A., Entringer, S., Fair, D. A., & Fortier, M. V. (2024). A global multicohort study to map subcortical brain development and cognition in infancy and early childhood. *Nature Neuroscience*, *27*(1), 176–186.

Amelia, T. M., & Latief, Y. (2022). Strategy for quality culture development of construction implementing service companies in running a quality management system based on professional culture and national culture to reduce construction failure rates. *International Research Journal of Engineering, IT & Scientific Research, 8*(4), 105–120. https://doi.org/10.21744/irjeis.v8n4.2136

Asadi, R., Rotimi, J. O. B., & Wilkinson, S. (2023). Rework causes classification model with liable parties of the contract in construction projects. *Frontiers in Built Environment, 9*, Article 1143829. https://doi.org/10.3389/fbuil.2023.1143829

ASTM International. (2020). *Standard test method for determining FF floor flatness and FL floor levelness numbers* (ASTM E1155-20). ASTM International.

Becker, S., Einizinab, S., Radanovic, M., Khoshelham, K., Mirzaei, K., & Fang, Y. (2023). Reality capture methods for remote inspection of building work. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLVIII-1/W2-2023*, 275–281. https://doi.org/10.5194/isprs-archives-XLVIII-1-W2-2023-275-2023

Budayan, C., & Okudan, O. (2022). Roadmap for the implementation of total quality management (TQM) in ISO 9001-certified construction companies: Evidence from Turkey. *Ain Shams Engineering Journal, 13*(6), Article 101788. https://doi.org/10.1016/j.asej.2022.101788

Bustamante-Sanchez, A., Villegas-Mora, B. E., Martínez-Guardado, I., Tornero-Aguilera, J. F., Ardigò, L. P., Nobari, H., & Clemente-Suárez, V. J. (2022). Physical activity and nutritional pattern related to maturation and development. *Sustainability*, *14*(24), 16958.

Cai, D., & Chai, S. (2023). Point cloud-based smart building acceptance system for surface quality evaluation. *Buildings, 13*(11), Article 2893. https://doi.org/10.3390/buildings13112893

Cao, Y., Liu, J., Feng, S., Li, D., Zhang, S., Qi, H., Cheng, G., & Chen, Y. F. (2022). Towards automatic flatness quality assessment for building indoor acceptance via terrestrial laser scanning. *Measurement, 203*, Article 111862. https://doi.org/10.1016/j.measurement.2022.111862

Einizinab, S., Khoshelham, K., Winter, S., Christopher, P., Fang, Y., Windholz, E., Radanovic, M., & Hu, S. (2023). Enabling technologies for remote and virtual inspection of building work. *Automation in Construction, 156*, Article 105096. https://doi.org/10.1016/j.autcon.2023.105096

Ghansah, F. A., & Edwards, D. J. (2024). Digital technologies for quality assurance in the construction industry: Current trend and future research directions towards Industry 4.0. *Buildings, 14*(3), Article 844. https://doi.org/10.3390/buildings14030844

Gumusburun Ayalp, G., & Arslan, F. (2025). Modeling critical rework factors in the construction industry: Insights and solutions. *Buildings, 15*(4), Article 606. https://doi.org/10.3390/buildings15040606

Gumusburun Ayalp, G., & Erdem, E. N. (2025). Unraveling the origins of construction rework: A holistic bibliometric analysis and exploration of causative factors. *Open House International, 50*(1), 65–97. https://doi.org/10.1108/OHI-10-2023-0235

Hayes, N. W., Maldonado, B. P., Tang, M., & Hun, D. (2024). Flat and Level Analysis Tool (FLAT) for real-time automated segmentation and analysis of concrete slab point clouds. In *Proceedings of the 41st International Symposium on Automation and Robotics in Construction (ISARC 2024)* (pp. 838–846). International Association for Automation and Robotics in Construction.

Khadim, N., Thaheem, M. J., Ullah, F., & Mahmood, M. N. (2023). Quantifying the cost of quality in construction projects: An insight into the base of the iceberg. *Quality & Quantity, 57*(6), 5403–5429. https://doi.org/10.1007/s11135-022-01574-8

Li, F., Li, H., Kim, M.-K., & Lo, K.-C. (2021). Laser scanning based surface flatness measurement using flat mirrors for enhancing scan coverage range. *Remote Sensing, 13*(4), Article 714. https://doi.org/10.3390/rs13040714

Luo, H., Lin, L., Chen, K., Antwi-Afari, M. F., & Chen, L. (2022). Digital technology for quality management in construction: A review and future research directions. *Developments in the Built Environment, 12*, Article 100087. https://doi.org/10.1016/j.dibe.2022.100087

Ma, Z., Liu, Y., & Li, J. (2023). Review on automated quality inspection of precast concrete components. *Automation in Construction, 150*, Article 104828. https://doi.org/10.1016/j.autcon.2023.104828

Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2010). *Code for acceptance of construction quality of building ground* (GB 50209-2010). China Planning Press.

Riaz, H., Khan, K. I. A., Ullah, F., Tahir, M. B., Alqurashi, M., & Alsulami, B. T. (2023). Key factors for implementation of total quality management in construction sector: A system dynamics approach. *Ain Shams Engineering Journal, 14*(3), Article 101903. https://doi.org/10.1016/j.asej.2022.101903

The Concrete Society. (2013). *Concrete industrial ground floors: A guide to design and construction* (Technical Report 34, 4th ed.). The Concrete Society.

Volkow, N. D., Gordon, J. A., Bianchi, D. W., Chiang, M. F., Clayton, J. A., Klein, W. M., Koob, G. F., Koroshetz, W. J., Pérez-Stable, E. J., & Simoni, J. M. (2024). The HEALthy Brain and Child Development Study (HBCD): NIH collaboration to understand the impacts of prenatal and early life experiences on brain development. *Developmental Cognitive Neuroscience*, *69*, 101423.

Willar, D., Trigunarsyah, B., Dewi, A. A. D. P., & Makalew, F. (2023). Evaluating quality management of road construction projects: A Delphi study. *The TQM Journal, 35*(7). https://doi.org/10.1108/TQM-04-2022-0132

Yarnold, J., Banihashemi, S., Lemckert, C., & Golizadeh, H. (2023). Building and construction quality: Systematic literature review, thematic and gap analysis. *International Journal of Building Pathology and Adaptation, 41*(5), 942–964. https://doi.org/10.1108/IJBPA-05-2021-0072