Tracking and Discussion of Construction Engineering Technologies in the Early 2020s

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Abstract

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Full Text

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Abstract

With the introduction of China’ s *14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through 2035*, alongside policies for improving housing quality, the construction engineering sector is entering a critical period of technological upgrading and industrial transformation. Based on the engineering practice of the 40-04 Regional Plot Project in Jinhui Town, Fengxian District, Shanghai (2023–2026), this paper systematically reviews technological advancements in four major areas of domestic and international construction engineering over the past five years. First, regarding deep foundation pit and pile foundation technologies, the focus is on innovative directions such as micro-disturbance retention technologies in subway-adjacent environments, air-supported foundation pit technologies, pile planting techniques, and the resource utilization of waste mud. Second, building materials and construction technologies are examined through the lens of high-performance waterproofing and fire protection systems, the application and promotion of Ultra-High Performance Concrete (UHPC), and material recycling under the "zero-waste construction site" concept. Third, the discussion addresses main structure and decoration/MEP technologies, focusing on the promotion of Modular Integrated Construction (MiC), ultra-low energy building technologies, and the integration of smart home systems. Finally, in construction informatization and project management, the analysis centers on AI-assisted design and review, digital twins, and smart operation and maintenance systems. This paper aims to provide a systematic summary and practical reference for the development of construction engineering technologies in the new era.

Keywords: Construction Engineering; Deep Foundation Pit Technology; Technological Advancements; AI On-site Construction Management

Introduction

The *14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through 2035* calls for building livable, innovative, smart, green, humanistic, and resilient cities [1]. The Ministry of Housing and Urban-Rural Development' s *Opinions on Improving Housing Quality* proposes that by 2030, significant progress will be achieved in housing quality improvement projects, with substantial enhancements in housing standards, design, materials, construction, and operation and maintenance, forming effective policy, standard, technical, and industrial systems to support these improvements.

These guidelines serve as important signposts for construction enterprises. This paper focuses on the past five years of domestic and international construction engineering developments across four domains: deep foundation pit and pile foundation technologies, building materials and construction (including waterproofing, fire protection, and main structural materials), main structure and decoration works, and construction informatization and project management, offering critical and constructive analysis from both summative and forward-looking perspectives.

1.1 Project Overview

The 40-04 Regional Plot Project (excluding pile foundations) in Jinhui Town, Fengxian District, Shanghai commenced in October 2023 and is scheduled for completion in September 2026. As of February 2026, the project team has applied for four patents (one authorized), published seven papers (including accepted manuscripts), and received two innovative QC awards from national-level associations.

1.2 Technical Tracking Framework for the Past Five Years

This paper examines four technological domains: (1) Deep foundation pit and pile foundation technologies, including subway-adjacent deep excavations, micro-disturbance retention, air-supported foundation pit technologies, pile planting, and waste mud reuse; (2) Building materials and construction, covering waterproofing materials and systems, fireproofing materials, UHPC for main structures, biochar concrete and calcined clay, and zero-waste construction sites; (3) Main structure, decoration, and MEP technologies, including modular integrated construction, super high-rise buildings, 3D printing, and ultra-low energy technologies; and (4) Construction informatization and project management, encompassing AI-assisted design and review, automated robotics, AI digital construction site management, and digital twins with smart operation and maintenance.

2.1 Deep Foundation Pit and Pile Foundation Technologies

Sun Li [2] identified the primary impacts of large foundation pit group excavation on existing urban rail transit tunnels as surface settlement, ground deformation, groundwater level changes, vibration and noise, effects on adjacent buildings, and construction techniques and support measures.

Jia Jian [3] summarized that in Shanghai' s soft soil, deep excavations require approximately two years for soil structure to consolidate and stabilize following disturbances from pile and enclosure construction, excavation unloading, dewatering consolidation, and construction traffic vibrations. Seven micro-disturbance design methods and technical measures were proposed: zoned unloading, steel support axial force servo systems, precision excavation and support based on soft soil rheological characteristics and time-space effects, micro-disturbance unloading above operating subways, micro-disturbance control during pile and enclosure construction, controlled dewatering and recharge, and full-process information-based monitoring.

Abudurusu · Abula [4] noted that air-supported membrane technology, as an emerging foundation pit protection method, has gradually become a focus in the engineering field due to its unique pneumatic membrane structure and fully enclosed construction space. This technology effectively reduces environmental pollution such as dust and noise during construction, offers excellent fire resistance, weather resistance, and self-cleaning properties, adapts to complex climatic conditions, and enhances construction safety and environmental performance.

Zhao Ben [5] described static drilling rooted piles as a new pile foundation form that creates a root-like pile-soil composite system through special construction processes tightly integrating the pile with surrounding soil, thereby improving bearing capacity and stability. Advantages include high bearing capacity, low noise and vibration, and relatively high construction efficiency.

Liang Zhihao [6] identified sludge dewatering as a critical challenge in waste mud treatment, with current methods primarily including evaporation, flocculation, centrifugation, and filtration. Soil extraction and testing followed by additive blending to form solidified soil represents a feasible construction technique for trench backfilling.

2.2 Building Materials and Construction

Wang Dongyan [7] summarized key issues in the waterproofing industry: inability to promote high-quality waterproofing materials, mismatch between engineering waterproofing design life and building service life, lack of international alignment in waterproofing standards, shortage of skilled professionals, unclear liability definitions for water leakage, weak awareness of waterproofing acceptance testing with outdated methods preventing effective supervision. Recommendations include accelerating development of high-performance waterproofing materials, enhancing technological innovation capabilities, developing compatible accessories and tools for various waterproofing materials, providing systematic waterproofing solutions, improving construction technical levels and management capabilities, developing portable leakage detection tools, and strengthening workforce training.

Wu Yong [8] noted that advances in nanotechnology and composite materials have significantly improved the performance and variety of new fire-resistant building materials, such as aerogel technology.

Chen Jiankang [9] explained that Ultra-High Performance Concrete (UHPC) derives its exceptional performance from a high-performance matrix composed of cement, ultra-fine powders, fine fillers, fine aggregates, fibers, and high-performance water reducers, combined with short fibers providing high tensile resistance. UHPC is essentially fiber-reinforced, super-plasticized concrete. Engineering applications in China have gradually expanded, exemplified by the Yuanjiahe Bridge on Shanghai's Jiamin Elevated Road completed in 2017, China' s first π-shaped UHPC highway bridge.

Huang Wenxiong [10] noted that to overcome application limitations of biochar in cement-based materials, researchers have developed multi-level modification techniques encompassing raw material pretreatment, preparation process optimization, and physical-chemical modification, effectively improving compatibility with cement matrices, reducing high water absorption, and enhancing mechanical properties and durability.

Luo Wen [11], citing the Ministry of Ecology and Environment' s Solid Waste and Chemicals Management Center' s May 2025 *Research Report on National Solid Waste Pollution Prevention Information Disclosure (2024)*, noted that in a 2023 survey of 315 cities nationwide, construction waste ranked third in generation volume, following only general industrial solid waste and agricultural waste. Technical responses include design optimization (BIM technology, permanent-temporary integration, standardization, modular design), construction optimization (containerized site dormitories, prefabricated construction enclosures, reducing cross-operations, rainwater recovery systems), and material upgrading (using recycled steel, recycled concrete, centralized steel processing, material recycling management).

Chang Yuting [12] defined ultra-low energy buildings as a new building type that, while ensuring indoor environmental comfort, achieves energy consumption far below traditional buildings through optimized architectural design, high-performance building envelopes, efficient energy systems, and renewable energy utilization. Key technical components include high-performance envelope technology, efficient heat recovery ventilation, and renewable energy utilization, while challenges include long cost recovery periods, difficult technical integration and coordination, and complex, costly maintenance.

2.3 Main Structure and Decoration/MEP Technologies

Cui Can [13] explained that Modular Integrated Construction (MiC) divides buildings into spatial modular units, completing up to 90% of prefabrication work in factories—including structural, finishing, plumbing, MEP, and HVAC work—before transporting to site for hoisting and assembly, requiring only limited on-site work for utility connections and finishing. Representative technologies include China Construction Haixing' s "Box-Formwork Cast-in-Place Modular Technology," Guangzhou Construction' s "High-Rise Concrete Modular Technology," China Construction Technology' s "Modular Technology Based on Superposed Shear Walls," China Construction Fourth Bureau' s "Formwork-Free Concrete Modular Technology," and Guangdong Construction Engineering Group' s "Apartment and Dormitory Modular Technology." Additionally, analysis of Boxabl' s core patent WO 2020/167673 A1 reveals planar laminated composite panel wall technology, with "SIPs + Precision Nodes + Folding Logic" representing the development direction for MiC.

Zhang Kun [14] noted that with the development of super high-rise construction, fundamental changes have occurred in building materials, vertical transportation equipment, and construction formwork and platforms. Since the 1980s, research has focused on high-strength, low yield-to-tensile ratio, weldability, durability, and fire resistance in steel. Over the past decade, China has further developed integrated platform equipment based on climbing formwork, using high-capacity "micro-convex fulcrums" and "space frames" as the platform' s structural skeleton, forming a giant steel hood covering the core tube upper sections. Key construction aspects include high-capacity pile foundations, top-down construction for basements, mass concrete, construction surveying, tower crane and construction elevator selection and layout, high-strength steel welding, high-strength concrete pumping to extreme heights, high-altitude worker safety, and mega steel component installation.

Li Jiaxin [15], Yu Lili [16], and Li Rongshuai [17] explained that 3D printing is a rapid prototyping technology that constructs objects by digitally modeling and printing layer-by-layer using bondable materials, also known as additive manufacturing due to its layered accumulation characteristics. 3D-printed buildings offer resource savings, cost reduction, shorter schedules, and design flexibility, with particular advantages in emergency housing, rural and disaster reconstruction, affordable housing in developing countries, and lunar construction using in-situ materials. However, constraints include difficulty with overhanging printed sections, strict environmental requirements, insufficient construction standards and codes, demands for project management transformation, and challenges in multi-printhead coordinated path planning.

2.4 Construction Informatization and Project Management

Xu Yuanchi [18] noted that for the architectural process, AI introduction during the pre-design planning phase can assist decision-making, and through artificial neural network simulation training, algorithms can align with architectural design codes and contemporary value systems. In the post-occupancy evaluation phase, AI (e.g., ANN models) can analyze objective normative value indicators more efficiently, completing underlying value logic determination and achieving non-hierarchical structure evaluation and weighting.

Chen Gang [19] emphasized that to achieve high-quality construction, robots must provide uniform substrates from the previous process step, continuously adjust actions using sensory feedback, and deeply understand material mechanical properties and inter-process influences.

Xue Wei [20] noted that AI has enabled applications such as safety helmet recognition, protective clothing detection, bare soil coverage monitoring, and earth truck cleaning detection.

Wang Tingdong [21] described an AI-based system, explaining both the construction process (system architecture, AI algorithm selection, and head-mounted integrated device determination) and, through pilot case applications, verified the system' s effectiveness in hidden danger investigation and management, hazardous operation management, safety acceptance, and electrical box inspection.

Wang Tingguo [22] identified digital fusion application methods as primarily including Building Information Modeling (BIM), digital twin technology, drones and laser scanning, intelligentization and IoT technology, cloud computing and big data analysis, and artificial intelligence applications.

Bian Shouguo [23] noted that intelligent building operation and maintenance management not only saves electricity, heat, and other energy sources but also achieves collaborative operation of electrical, HVAC, lighting, elevator, fire protection, and security equipment through cloud computing and AI monitoring of maintenance processes, improving operational energy efficiency.

Conclusion

Based on the 40-04 Regional Plot Project in Jinhui Town, Fengxian District, Shanghai, this paper has conducted systematic tracking and analysis of recent developments in domestic and international construction engineering over the past five years, focusing on four directions: deep foundation pit and pile foundation technologies, building materials and construction, main structure and decoration/MEP, and construction informatization and project management.

In deep foundation pit and pile foundation technologies, micro-disturbance control, air-supported excavation support, and static drilling rooted piles have demonstrated significant effectiveness in improving construction safety and reducing environmental disturbance, while waste mud resource utilization has gradually advanced toward practical engineering application. In building materials and construction, applications of high-performance materials such as UHPC, biochar concrete, and aerogel fireproofing materials continue to expand, while systematic, standardized waterproofing systems urgently require strengthening. The "zero-waste construction site" concept is gradually being implemented, and ultra-low energy building technology systems are becoming increasingly mature. Regarding main structure and decoration/MEP, MiC technology is driving the industrialization of construction, super high-rise construction equipment and formwork systems continue to upgrade, and 3D printing technology demonstrates unique advantages in specific scenarios while still facing challenges of missing standards and process coordination. In construction informatization and project management, technologies such as AI-assisted design, intelligent construction site management, and digital twin operation and maintenance are accelerating digital integration across the building lifecycle, promoting comprehensive improvements in engineering quality, safety, and energy efficiency.

Overall, construction engineering technology is in a critical transition phase from "industrialization" toward "intelligence, greening, and integration." In the future, construction enterprises should further strengthen integrated application and engineering validation of emerging technologies, promote the coordinated development of standard systems and industries, and contribute to achieving the goals of building livable, resilient, and smart cities.

References

[1] State Council of the People's Republic of China. The 14th Five-Year Plan for National Economic and Social Development of the People' s Republic of China and the Long-Range Objectives Through 2035[M]. 1st ed. Beijing: People' s Publishing House, 2021.

[2] Sun L, Dai Y, Luo M, et al. Influence of large foundation pit group excavation on existing urban rail transit tunnels and safety risk control technologies[J]. Water Resources and Hydropower Engineering (Chinese and English), 2025, 56(S2): 611-618.

[3] Jia J, Xie X L, Zhai J Q, et al. Micro-disturbance technology for deformation control in soft soil foundation pits[J]. Journal of Shanghai Jiao Tong University, 2016, 50(10): 1651-1657.

[4] Abudurusu・Abula. Construction technology of air-supported membrane for foundation pits and its empirical study in construction sites[J]. Engineering Construction and Design, 2025(07): 251-253.

[5] Zhao B. Application and research of static drilling rooted piles in high-rise

buildings[J]. Urban Architecture, 2025, 22(23): 136-141.

[6] Liang Z H, Tang J J. Research on treatment and reuse technology of construction waste mud[J]. Scientific and Technological Innovation, 2020(27):

[7] Wang D Y, Xiao X W, Xiao J Z, et al. Research on current status and development strategy of engineering leakage prevention in China[J]. Industrial Architecture, 2022, 52(04): 186-191.

[8] Wu Y. Research progress in building fire protection technology[J]. China Building Materials Science and Technology, 2025, 34(04): 29-32.

[9] Chen J K. Research progress on mechanical properties of ultra-high performance concrete (UHPC)[J]. Science China: Physics, Mechanics and Astronomy, 2024, 54(05): 148-167.

[10] Huang W X. Review of research on biochar modified concrete[J]. China Cement, 2025(11): 9-12.

[11] Luo W. Research on implementation path and benefits of "zero-waste construction site" [J]. Construction Technology, 2025, 9(10): 32-35.

[12] Chang Y T. Application and development of ultra-low energy building technology in construction engineering[J]. Forestry Science and Technology Information, 2025, 57(01):

[13] Cui C, Ouyang W. Research on development of concrete modular integrated construction (MiC) technology[J]. Modern Engineering Technology, 2025, 4(22):

[14] Zhang K. Development and prospect of super high-rise building construction technology[J]. Construction Technology, 2018, 47(06): 13-18.

[15] Li J X, Wang J J, Wu L M, et al. Research, application status and prospect of 3D printing technology in construction industry[J]. Technology Wind, 2022(11): 78-83.

[16] Yu L L, Fang W X, Chen J D, et al. Research progress of 3D printing technology in construction industry[J]. Guangdong Building Materials, 2025, 41(07):

[17] Li R S. Research direction and progress of key technologies for 3D printing in construction[J]. Building Construction, 2017, 39(2): 248-250.

[18] Xu Y C, Wei G N. The closed loop of architectural process: Analysis of AI participation in pre-design planning and post-occupancy evaluation[J]. Huazhong Architecture, 2026, 44(02): 104-107.

[19] Chen G. Current status and future prospects of construction robot research and development[J]. Construction Enterprise Management, 2025(11): 34-38.

[20] Xue W. Application practice of artificial intelligence technology in construction engineering[J]. Shanghai Construction Science and Technology, 2025(04): 41-44.

[21] Wang T D, Han Y H, Li S, et al. Construction and application of AI-based construction site safety management system[J]. Project Management Technology, 2025, 23(10): 43-50.

[22] Wang T G. Exploration and practice of digital fusion application in construction[J]. Fujian Architecture, 2024(09): 76-81.

[23] Bian S G. Discussion on digital twin technology empowering building operation and maintenance[J]. Housing and Real Estate, 2023(25): 22-24.

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CUI Lei: Proposed research ideas, drafted the manuscript, and revised the final version.

Note: Figure translations are in progress. See original paper for figures.