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Technical Application and Teaching Research Optimization of Civil Engineering Detailed Design Driven by BIMMAKE

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Abstract: To address the challenges in traditional civil engineering detailed design, such as insufficient three-dimensional spatial representation, poor technical implementability, and ineffective multidisciplinary collaboration, and to align with the construction industry's demand for technical talents driven by digital transformation, this paper takes the BIMMAKE software as the core technical platform. It systematically analyzes its core technical application pathways in civil engineering detailed design, focusing on the technical optimization logic in key scenarios like secondary structures, steel reinforcement joints, and formwork configuration. By integrating teaching practices, an integrated system of "technology empowerment-design implementation-teaching-research collaboration" is constructed. Through deepening the integration of technology and design, targeted teaching-research optimization strategies are proposed. This aims to establish a teaching model that aligns with industry technological advancements, providing technical support and practical guidance for the reform of digital detailed design education in civil engineering, thereby fostering the cultivation of versatile design talents proficient in cutting-edge technologies.

Keywords: BIMMAKE; civil engineering detailed design; technical application; design optimization; teaching-research strategy; digital transformation

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1. Introduction

The deep integration of construction industrialization and digitalization is driving the advancement of civil engineering detailed design from an iteration of traditional two-dimensional drawings towards three-dimensional digitization, technical precision, and design collaboration. Technological innovation has become the core force driving the improvement of detailed design quality and efficiency. Building Information Modeling (BIM) technology, with its core advantages such as information integration, visual simulation, and collision detection, has become the mainstream technical support for civil engineering detailed design [1]. As a specialized BIM software focusing on the construction phase, BIMMAKE, by virtue of its technical characteristics including localized technical adaptation, efficient modeling algorithms, and precise detailing functions, has achieved full-process coverage from model construction to technical implementation in civil engineering detailed design scenarios. Its technical application logic is highly aligned with actual engineering needs, providing a crucial vehicle for the technological advancement and pedagogical innovation of civil engineering detailed design [2].

Current issues persist in the field of civil engineering detailed design, such as a disconnection between technology and design, and prominent bottlenecks in traditional techniques: two-dimensional design modes struggle to convey the technical expression of complex nodes, leading to discrepancies between design intent and on-site construction implementation; the application of detailed design technologies is fragmented, lacking a systematic understanding of the full-process integration of BIM technology; in teaching, the separation of technical instruction from design practice makes it difficult for students to grasp the optimization logic of technology within actual design workflows [3]. Based on this, this paper, grounded in the technical features of BIMMAKE, deeply explores its application value in civil engineering detailed design, optimizes the integration path between technology and design, and simultaneously constructs a teaching-research system adapted to technological development. This aims to provide a forward-looking framework for the technological advancement and talent cultivation in civil engineering detailed design.

2. Core Technology and Design Integration Pathways of BIMMAKE in Civil Engineering Detailed Design

The technical advantages of BIMMAKE are concentrated in areas such as localized adaptation, parametric modeling, and full-process collaboration. Its integration with civil engineering detailed design focuses on using technology to drive design optimization, achieving a technical closed loop from model construction to construction implementation, thereby enhancing the precision, operability, and economic efficiency of detailed design.

2.1. Foundation Modeling, Data Compatibility Technology, and Design Adaptation

BIMMAKE's intelligent model reconstruction and multi-format data compatibility technology provide an efficient and precise foundation for civil engineering detailed design. This relies on its proprietary two-dimensional drawing vectorization recognition algorithm and parametric model generation engine. The software can automatically parse layer information, line type annotations, and dimensional parameters in CAD drawings. Through component feature extraction technology, it accurately identifies main structural components such as columns, walls, beams, and slabs. Combined with a built-in structural component rule library (covering concrete strength grades and standard value ranges for component cross-sectional dimensions), it enables intelligent matching and rapid conversion of component attributes. Through technical means such as layer purification (batch deletion of redundant annotation layers and auxiliary line layers), drawing standardization preprocessing (correcting broken lines, unifying annotation styles), and component boundary threshold calibration, the accuracy of model reconstruction can be increased from a default 95% to over 98%. The time required for reconstructing the main structure of a single 12-story residential building can be controlled within 2-3 hours, representing an efficiency improvement of over 80% compared to traditional manual modeling. This significantly reduces foundational modeling workload, allowing designers to focus on core detailing tasks, as detailed in Table 1.

Table 1. Core Performance Comparison of Different Modeling Approaches.

Modeling Approach	Model Reconstruction Accuracy (%)	Modeling Time (12-Story Main Structure) (h)	Data Compatibility (Supported Formats)	Cross-Software Data Loss Rate (%)
BIMMAKEIntelligent Model Reconstruction	≥ 98((after preprocessing))	2-3	Revit, GTJ, IFC4.3, Navisworks	≤ 1.2
Traditional AutoCAD Manual Modeling	Reliant on human expertise (average 82)	12-15	CAD format only	Unable to transfer directly across software

Generic BIM Software Model Reconstruction	90-92	6-8	IFC4.0, Revit	3.5-5.0

Simultaneously, as shown in Table 1, the software adopts a multi-format data compatibility interface based on the IFC4.3 standard, supporting one-click import of mainstream software formats such as Revit, GTJ calculation models, and Navisworks. Through lossless data mapping technology, it achieves complete transfer of component attributes, material information, and engineering quantity data. This addresses issues of data loss and attribute misalignment in cross-software modeling, realizing the design goal of "one model, multiple uses." The detailed design model can seamlessly interface with quantity calculation, construction simulation, schedule management, and other processes, establishing a full-process design data chain. This provides precise data support for design decision-making, thereby avoiding the technical deviations caused by data fragmentation across multiple stages in traditional design.

2.2. Key Scenario Detailing Technology and Design Optimization Practice

Leveraging the core technologies of BIMMAKE, such as parametric editing, visual simulation, and algorithmic optimization, enables the precise implementation of key scenarios in civil engineering detailed design, addressing challenges in traditional design such as difficult control of complex nodes and poor construction adaptability. In the detailed design of secondary structures, the software, based on the standardized parametric system built into the Code for Acceptance of Construction Quality of Masonry Structures (GB 50203), incorporates a masonry layout optimization algorithm [4]. According to technical requirements such as block specifications (common dimensions like 600mm200mm200mm), mortar joint thickness (default 8-12mm, supports custom adjustment), lap length (should not be less than 25mm), and tooth joint dimensions (60mm*60mm), it can automatically generate layout schemes. Simultaneously, it performs dynamic algorithmic optimization for complex areas including door and window openings, wall corners, and junctions with the main structure. Through iterative calculations aimed at minimizing the use of non-standard blocks, it controls the proportion of non-standard blocks to within 5%. It concurrently generates a detailed material list containing block types, quantities, and laying sequences, achieving precise technical alignment between the design scheme and material control as well as construction techniques, thereby balancing masonry efficiency with structural stability.

In the reinforcement detailing phase, BIMMAKE, with its parametric reinforcement family library and code-compliant database as the core support, incorporates an automatic reinforcement anchorage length calculation module (which dynamically adapts based on concrete strength grade, reinforcement grade, and seismic level; for instance, the seismic anchorage length for HRB400 reinforcement in C30 concrete is 37d). This enables precise design of details such as reinforcement anchorage length, tie spacing, and hook angles (135° for seismic components, 90° for non-seismic components). The software employs a three-dimensional grid-based collision detection algorithm to conduct comprehensive multi-dimensional conflict detection for reinforcement at critical locations such as beam-column joints, primary-secondary beam intersections, and slab-beam reinforcement overlaps. The detection accuracy reaches millimeter level. It automatically marks conflict locations and provides optimization suggestions (e.g., adjusting reinforcement layout hierarchy, optimizing anchorage direction). Through technical optimization to adjust the layout scheme, it avoids rework caused by on-site reinforcement tying interference, ensuring both structural safety and construction operability.

As detailed in Table 2, the software employs an automated formwork layout engine and a support system mechanical simulation module for template layout detailing. Based on the cross-sectional shape of components and the lateral pressure of concrete (dynamically calculated according to pouring height and speed), it can quickly compute the formwork contact area, automatically match wood/steel formwork specifications, and optimize the layout of support points (upright spacing not exceeding 1.5m, ledger spacing not exceeding 1.8m) and installation sequences. Utilizing a formwork turnover efficiency optimization algorithm, it maximizes the reuse of the same formwork across different components. Furthermore, it can export formwork layout construction drawings, formwork quantity lists, and support system load-bearing verification reports. This achieves deep integration between the design scheme and construction technology, cost control, and mechanical safety, establishing a closed-loop logic of "technology optimizing design, design guiding construction."

Table 2. Comparison of Technical Indicators Between BIMMAKE and Traditional Design Methods in Key Scenarios.

Detailed Design Scenario	Core Technical Indicator	Performance with BIMMAKE	Performance with Traditional Design Methods	Technical Improvement Benefit
Secondary Structure Masonry	Non-Standard Block Proportion (%)	≤5 (after algorithmic optimization)	15-22	Material waste reduced by over 70%
Reinforcement Joint Design	Joint Conflict Detection Accuracy (%)	≥99 (millimeter-level precision)	65-70 (manual inspection)	On-site rework rate reduced by over 90%
Formwork Layout Design	Formwork Reuse Rate (%)	≥85 (optimized by reuse algorithm)	55-60	Formwork cost savings of 25%-30%
Support System Design	Load-Bearing Verification Pass Rate (%)	100 (mechanical simulation module)	80-85 (empirical formula calculation)	Structural safety risk significantly reduced

2.3. Collaborative Detailing Technology and Design Deliverable Implementation

BIMMAKE's cloud collaboration and mobile interaction technologies, leveraging cloud computing and lightweight data transmission, redefine the multidisciplinary collaboration mode in civil engineering detailed design and facilitate the efficient implementation of design deliverables. The software employs a distributed cloud storage architecture, supporting multidisciplinary designers (structural, MEP, construction) in conducting real-time collaborative work based on the same model. Model modifications are synchronized in real-time, with full traceability of change records (including editor, timestamp, modification content, and version iteration). Through hierarchical permission control (distinguishing roles such as design lead, discipline designer, and reviewer), it addresses issues of design conflicts arising from lagging multidisciplinary communication and information asymmetry in traditional design, enabling collaborative detailing between structural and MEP systems and proactive clash avoidance. Furthermore, the software supports compressing the detailed model into a lightweight format (reducing file size by over 80% compared to the original model) and generating a unique QR code. Scanning this code via the mobile app allows viewing of detailed drawings, technical parameters, and the 3D model, with interactive operations such as model rotation, sectioning, and annotation. This enables real-time alignment between design intent and construction phases, mitigating challenges associated with information distortion and unclear expression of complex nodes in traditional paper-based briefings. In the design deliverable submission phase, the software can directly export CAD construction drawings compliant with industry standards (preserving layer information and annotation styles), PDF briefing documents, and seamlessly interface with BIM5D schedule management platforms. This transforms detailed design deliverables into foundational data for construction schedule control (e.g., component quantities, construction node timelines), ensuring that detailed design outcomes precisely serve construction schedule management and complete the technical implementation loop from design to construction.

3. Teaching-Research Optimization Strategies for BIMMAKE Technology-Enabled Civil Engineering Detailed Design

Based on the requirements for integrating BIMMAKE technology application with civil engineering detailed design, teaching and research work must break away from the traditional model that "separates technical instruction from design practice." It is necessary to construct a teaching-research system centered on technology, guided by design, and supported by practice, aiming to cultivate students' technical application abilities and innovative design thinking.

3.1. Constructing a Technology-Design Integrated Teaching Content System

Taking the core technologies of BIMMAKE as the main thread, the teaching content framework should be restructured to eliminate fragmented technical explanations and strengthen the logic of integrating technology with design. The teaching content must cover three major modules: foundational modeling technology, key scenario detailing technology, and collaborative design technology. Emphasis should be placed on explaining how technical parameter settings impact design outcomes. This should be combined with analyzing typical engineering cases to explore the core rationale of technology-optimized design. For example, using secondary structure detailing cases to explain design adaptation techniques like masonry layout algorithms and non-standard block control; through reinforcement joint cases, elucidating the balancing logic between collision detection technology and structural safety design. Simultaneously, introducing cutting-edge industry technology trends and supplementing with extended content such as AI-aided design and AR visual briefings will broaden students' technical horizons and enhance their design foresight [5].

3.2. Innovating Technology-Driven Teaching Methods

Adopt a three-phase teaching method of "technical hands-on practice - design optimization - project review," using real engineering projects as the vehicle to guide students in applying BIMMAKE technology to solve design challenges. Through hands-on technical practice, students master the software's core functions, then proceed to technically optimize designs based on project requirements. Finally, they review the feasibility of their design schemes in light of actual engineering, cultivating a mindset of "using technology to support design, and using design to validate technology." Introduce a school-enterprise collaborative teaching mechanism by inviting enterprise technical experts to participate in instruction, sharing their experience in applying BIMMAKE technology and design optimization cases from real projects, thereby bridging technology and engineering practice [6]. Concurrently, utilize online practical training platforms to provide diverse technical practice resources, supporting students in independently conducting technical exercises and design innovation to enhance their self-directed learning capabilities.

3.3. Strengthening the Technical Proficiency of "Dual-Qualified" Teaching Staff

The development of the teaching faculty must focus on the dual enhancement of technical capabilities and design experience, establishing a systematic training system. Regularly organize teachers to participate in official advanced technical training for BIMMAKE, ensuring in-depth mastery of the software's new version features and technical application scenarios, while concurrently studying industry standards and technological frontiers in civil engineering detailed design. Arrange for teachers to undertake internships or work placements at construction enterprises and design institutes, participating in the BIM detailed design work of actual projects. This will accumulate practical experience in technical implementation and design cases, achieving a competency loop of "technical instruction - design guidance - engineering practice." Establish teaching-research communities, bringing together university faculty and enterprise technical personnel to conduct joint research projects. Explore innovative pathways for integrating BIMMAKE technology with civil engineering detailed design, and translate research findings into teaching content to enhance teaching quality.

3.4. Optimizing the Technology-Oriented Assessment and Evaluation Mechanism

Move beyond the traditional written examination model to establish a diversified assessment system centered on technical application ability and design optimization effectiveness. The assessment content should encompass four dimensions: accuracy of technical operation, reasonableness of design solutions, innovativeness of technical optimization, and efficiency of collaborative design. Emphasis should be placed on evaluating students' ability to use BIMMAKE technology to solve complex design problems. For example, through assigned design tasks, assess the application effectiveness of students' use of collision detection technology and parametric editing technology, as well as the economic viability and construction operability of their design solutions. Introduce an enterprise evaluation component, where enterprise technical personnel review and score students' design deliverables based on their technical implementability. This ensures assessment outcomes align with industry needs and guides students to focus on the practical application value of technology and design [7].

4. Conclusion and Outlook

BIMMAKE, as a core digital tool in the field of civil engineering detailed design, provides crucial support for addressing the bottlenecks of traditional design and driving design advancement through its technological applications. By deeply integrating core technologies such as intelligent model reconstruction, parametric optimization, and collaborative interaction with civil engineering detailed design, it enables comprehensive improvement in design accuracy, efficiency, and operability. This fosters a virtuous cycle of "technology driving design, and design feeding back into technology," injecting momentum into the digital transformation of civil engineering detailed design. Simultaneously, the established technology-design integrated teaching-research system can effectively address the disconnect between technology and practice in traditional education, cultivate versatile digital design talents that meet industry demands, and provide practical reference for the pedagogical reform in civil engineering disciplines.

Looking ahead, with the deep integration of technologies such as AI, AR, IoT, and BIMMAKE, civil engineering detailed design will undergo leapfrog development toward intelligentization, full-lifecycle management, and cross-domain collaboration. On one hand, BIMMAKE technology will achieve iterative upgrades in its core functionalities. Equipped with AI-powered intelligent design engines, it will enable the automatic generation and optimization of secondary structure layouts and reinforcement joint designs based on design codes and engineering case studies, reducing manual intervention. By integrating AR immersive briefing technology, it will allow for the overlay of on-site actual scenes with BIM models, facilitating the visual preview and construction guidance of detailed design schemes. Through the integration of IoT sensor data, real-time monitoring of component installation accuracy and formwork stress states during construction will be possible, forming a dynamic closed loop of "design-construction-monitoring-optimization," thereby further enhancing the technical sophistication and implementation efficiency of detailed design. On the other hand, detailed design will extend beyond the confines of the construction phase alone, reaching across the entire project lifecycle to achieve integrated technical collaboration among design, construction, and operation and maintenance. BIMMAKE models can serve as the core data carrier for the entire project lifecycle, enabling data inheritance and reuse from preliminary detailed design to later-stage operation, maintenance, and inspection. Teaching and research efforts must keep pace with technological trends, continuously optimizing teaching content and methods, with a focus on imparting cutting-edge technologies such as AI-aided design, AR technology application, and full-lifecycle collaboration. By aligning with the practical project needs of enterprises, students' innovative thinking in technology will be cultivated, driving the iteration of civil engineering detailed design technology and the upgrading of talent development, thereby supporting the high-quality digital transformation of the construction industry. Additionally, interdisciplinary collaborative research should be strengthened to explore the integration pathways between BIMMAKE technology and green building (e.g., optimization of low-carbon material usage) as well as smart construction (e.g., detailed adaptation for prefabricated components), providing core technical support for the sustainable development of the industry.

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