

Construction and Application of the Teaching Mode for the Building Structure Course Based on BIM Technology

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Abstract: The long-standing two-dimensional graphical representation and discretized mechanical analysis paradigm in the building structure course have caused significant information transmission losses when presenting the spatial topological relationships of complex systems and the collaborative logic of multiple disciplines. BIM technology, with its core feature of using a parametric three-dimensional digital model as the sole data source, provides a technical pivot for reconstructing the information carrier and interactive depth of structural teaching. This paper, based on an examination of the limitations of existing teaching methods, analyzes the adaptation mechanism between the core representations of BIM and the essential elements of structural teaching. Then, it constructs a teaching mode for the building structure course based on BIM technology from three dimensions: the hierarchical resetting of teaching objectives, the modular reorganization of teaching content, and the integrated design of visualized evaluation. Furthermore, it proposes a systematic implementation framework covering stage division, resource clustering, and adaptive guidance. This mode aims to shift structural teaching from passive verification to a cognitive level of active optimization and collaborative decision-making.

Keywords: BIM technology; building structure course; teaching mode; parametric modeling; collaborative analysis; modular teaching

Introduction

As a core component of the civil engineering discipline, the teaching effectiveness of the building structure course directly affects learners' systematic understanding of structural mechanics behavior and construction logic. Constrained by the expressive boundaries of two-dimensional static media, the traditional teaching paradigm struggles to establish a continuous mapping between abstract formula derivation and spatial force visualization, nor can it effectively simulate the dynamic interference and data integration requirements in a multi-disciplinary collaborative context. With the paradigm shift of engineering information delivery standards from discrete files to continuous data flows in the process of digital construction, the existing course system shows an increasingly significant adaptive gap between the teaching supply side and the industry demand side. The parametric driving mechanism and multi-disciplinary integration verification logic embedded in BIM technology provide an operable underlying architecture to resolve the cognitive loss and information silo dilemma in structural teaching. Exploring the reconstruction path and implementation framework of the teaching mode for the building structure course under the intervention of BIM technology has necessary theoretical value and pedagogical innovation significance for promoting the synchronous resonance between the course content sequence and the contemporary engineering information flow logic.

1. Review of the Teaching Reality of the Building Structure Course and the Logic of BIM Technology Intervention

1.1 Diagnosis of the Limitations of the Existing Teaching Mode of the Building Structure Course

The building structure course has long followed the teaching paradigm centered on two-dimensional engineering drawing expression and mechanical analysis. Its information transmission carrier mainly relies on plan drawings, formula derivation, and component checking procedures. This mode presents significant cognitive loss when displaying the spatial topological relationships and load

transfer mechanisms of complex structural systems. Students often find it difficult to establish a continuous representation of structural mechanical behavior between discrete beam-column reinforcement details and abstract internal force envelope diagrams. Furthermore, the fragmentation between manual modeling and numerical analysis tools in the course design stage further intensifies the friction in transforming design intent into computational models. Consequently, the optimization decision-making process of structural selection and joint detailing is simplified into a table-checking confirmation of established specification clauses, which weakens the teaching effectiveness in cultivating iterative thinking guided by structural performance.

Another limitation of the existing teaching resource allocation lies in the insufficient vertical integration and horizontal linkage among knowledge modules. Concrete structure, steel structure, seismic design, and other sub-courses each maintain their own independent example systems and construction standards. When students face comprehensive structural design tasks in a multi-disciplinary collaborative context, they generally encounter the information silo dilemma of redundant reconstruction of model data and version replacement. The static knowledge transmission mode solidified by two-dimensional media fails to effectively simulate the dynamic interference during the construction process and the assembly logic of prefabricated components. This creates an unbridgeable gap between the teaching scenario and the continuous information transmission demand at the front end of engineering construction, directly restricting learners' cognitive breadth and depth regarding the industrialized construction process of modern structures^[1].

1.2 Analysis of the Adaptability between the Core Representations of BIM Technology and the Teaching Elements of the Building Structure Course

The core feature of BIM technology, which uses a parametric three-dimensional digital model as the sole data source, precisely matches the inherent demands of the building structure course for the visualization of spatial geometric invariance and stress deformation in teaching. The cross-sectional geometric information, material constitutive properties, and boundary constraints contained in structural components achieve semantic-level association and definition in the BIM environment. Any modification to a cross-section can instantly trigger the synchronous update of the associated plane drawing expression and the linked recalculation of quantities. This object-oriented expression mechanism driven by the parametric kernel can materialize abstract elastic modulus settings and load combination coefficients into interactive digital twin entities, thereby providing a high-fidelity virtual testing ground for the intuitive interpretation of structural mechanical responses and the pre-simulation of failure modes.

The multi-disciplinary collaborative workspace and collision detection logic provided by BIM technology further reshape the organizational relationship and transmission path of the teaching elements of the structure. The integrated verification of the structural analysis model, the building space enclosure model, and the electromechanical pipeline layout model within a unified coordinate system provides a context for necessity derivation based on conflict resolution for structural openings and reinforcement measures that originally had clear boundaries in professional cognition. In the teaching dimension, this technical adaptability is manifested in instructing the logical generation of structural components not as an isolated result of mechanical calculation, but as a dynamic correction process based on spatial occupancy coordination and process simulation feedback. Thus, it shifts structural teaching from passive verification and recitation of construction details to the cognitive level of active optimization and systematic decision-making.

1.3 Theoretical Basis for Curriculum Reconstruction from the Perspective of Digital Information Integration

From the perspective of cognitive constructivism, the intervention of BIM technology in the teaching of the structure course is not merely a simple iteration of technical tools, but rather a fundamental reconstruction of the representational state and interactive depth within the learning context. By eliminating the semantic gap between the abstract symbolic system and the physical entity representation, the digital information integration platform constructs a miniature engineering world for learners that allows direct manipulation and immediate feedback. In this simulated environment, the underlying mechanical mechanisms and construction logic within the structural concept system no longer rely on the linear translation of linguistic symbols. Instead, they form embodied spatial schematic memory through visual retention and dynamic navigation. This knowledge internalization path based on multi-modal perception channels significantly reduces the cognitive load from solving

sectional forces to imagining spatial truss models^[2].

The theoretical basis from the perspective of information integration is also reflected in the possibility of non-linear reorganization of the course content sequence. The BIM central database breaks the mandatory linear arrangement of traditional textbooks organized by chapter and allows the horizontal retrieval of holographic data flows of geometry, materials, loads, construction details, and construction processes anchored to specific structural systems or typical joints. This data penetration capability provides the underlying architectural support for the modular deconstruction and project-driven orientation of teaching content, enabling the closed-loop process of "structural selection - analysis and verification - joint design - drawing expression" to be seamlessly connected within the same digital environment. The theoretical legitimacy of curriculum reconstruction lies in its conformity to the inevitable trend of engineering information transforming from discrete file delivery to continuous data flow in contemporary construction activities, ensuring the synchronous resonance between the teaching supply side and the industry demand side at the level of information exchange standards.

2. Systematic Construction of the Teaching Mode for the Building Structure Course Based on BIM Technology

2.1 Hierarchical Resetting of Teaching Objectives Oriented Toward Structural Cognition and Collaborative Analysis

The teaching objectives of the traditional structure course rely on three relatively closed stages: cross-section strength verification, serviceability limit state checking, and selection of construction details, presenting a linear progressive logic from single-component mechanical analysis to overall structural design. After the intervention of BIM technology, the reconstruction of teaching objectives integrates the above discrete indicators into a three-dimensional progressive system driven by structural performance. The basic level focuses on the accurate establishment of the parametric component information model and the object-oriented associative cognition of cross-section mechanical properties. The intermediate level targets the visual interpretation of the overall structural response laws under multiple load case combinations and scheme comparison and selection. The advanced level extends to collision detection, joint deepening coordination, and continuous transmission control of change data in a multi-disciplinary integrated environment. Thus, it realizes the cognitive shift from isolated component verification to systematic collaborative decision-making^[3].

The hierarchical resetting logic of teaching objectives is also reflected in the explicit definition and graded requirements for collaborative analysis ability. Supported by the BIM workflow, the teaching expectations of the structure course are no longer limited to the accuracy of internal force calculation and the rationality of reinforcement within the structural discipline itself. Instead, learners are required to possess a two-way coordination awareness of interpreting building clearance constraints and identifying the weakening effect of equipment pipeline crossing paths on structural components in a shared parameter environment. This goal shift demands that the teaching objective system incorporates the interpretation capability of collision reports, the optimization strategy of structural cross-sections under the clear height analysis framework, and the construction feasibility prediction based on process simulation into the evaluation scope. Consequently, it promotes the transformation of structural teaching output from a technical executor with a single calculation skill to a system constructor mastering the digital collaborative analysis paradigm.

2.2 Modular Reorganization and Ordering of Teaching Content under BIM Data Integration

The BIM data environment provides an operable underlying architecture for teaching content to break free from the mandatory linear arrangement of traditional chapters. Its core lies in extracting, decoupling, and regrouping existing knowledge units based on the complete life-cycle data flow of the structural system. Teaching content modules can be divided into four relatively independent yet progressively advanced logical units according to the level of information development of the BIM model: the conceptual massing exploration module, the physical model analysis module, the detailed design data generation module, and the construction simulation and visualization module. The conceptual massing exploration module focuses on the rapid establishment of structural system selection and basic geometric topological relationships. The physical model analysis module concentrates on material nonlinearity settings, load path demonstration, and overall index output verification. The detailed design data generation module covers rebar joint arrangement rules,

connection detail library invocation, and plan drawing customization. The construction simulation and visualization module introduces the timing of temporary structure intervention and the lifting path simulation of prefabricated components.

The sequencing principle of the reorganized teaching content modules follows the inherent timing of BIM data flow and the progressive logic of structural design decision-making, rather than simply adopting the traditional division by material type or force form. Each module is connected through explicit logical links driven by parameter changes in the central model. The geometric positioning information and cross-section definition data output from the preceding module directly serve as the boundary input for the subsequent module's analysis and calculation, thereby forcing the global propagation perception of design intent changes in the teaching content sequence. The sequencing process of teaching content simultaneously incorporates training elements of data management dimensions such as model version comparison, dynamic clearance detection, and quantity difference tracking, enabling learners to naturally acquire the structural collaborative design thinking paradigm based on a single data source and the awareness of data asset management while progressing through each module^[4].

2.3 Integrated Design of Visualization-Based Interactive Methods and a Multi-Dimensional Evaluation Mechanism

The visualization-based interactive methods strive to transform the BIM model from a static result presentation medium into a dynamic cognitive construction tool. The interactive logic is planned around three core dimensions: sectional perspective observation, parameter-driven deformation, and time dimension unfolding. Sectional perspective observation grants the view operation rights of arbitrary plane sectioning and box isolation, which are used to reveal the spatial orientation of the rebar cage inside components, the stirrup densification configuration at joint core areas, and the internal interface relationships of composite sections. Parameter-driven deformation converts abstract indicators such as inter-story drift ratios and the sequence of plastic hinge formation into animated physical responses of the structure under lateral loads by mesh coloring and displacement cloud map overlay associated with finite element analysis results. Time dimension unfolding achieves the simulated layer-by-layer growth of the main structure by linking construction schedule data, simultaneously presenting the gradual mechanical state changes during the erection of the support system and the closure timing of post-casting strips.

The multi-dimensional evaluation mechanism is deeply integrated with the visualization-based interactive process, forming three evaluation quadrants: model data compliance verification, quantitative indicator output for scheme comparison and selection, and collaborative process traceability analysis. Model data compliance verification focuses on the consistency of component naming conventions, the accuracy of cross-section library invocation, and the logical self-consistency of node degree-of-freedom constraint settings. The quantitative indicator output for scheme comparison and selection relies on the automatic statistics and extraction of converted concrete thickness, steel consumption distribution, and component stress ratio ranges from the BIM schedule. Collaborative process traceability analysis evaluates the information interaction efficiency in a multi-disciplinary environment by recording the initiator of conflict events, the response time, and the resolution path. The integrated design ensures that the evaluation actions are embedded in the visualization-based operation process as immediate diagnosis and adaptive feedback intervention, rather than as a summative measurement independent of the teaching process.

3. Implementation Path and Application Framework of the BIM Teaching Mode for the Building Structure Course

3.1 Stage Division of the Teaching Process and BIM Task-Driven Organizational Procedure

The teaching process is divided into three stages according to the progressive rule of the information depth of the BIM model: the basic modeling cognition period, the structural analysis and optimization period, and the collaborative deepening and integration period. The basic modeling cognition period focuses on the definition of parametric component families, the spatial anchoring of the level and axis network system, and the semantic association assignment of material properties, allowing learners to establish the digital mapping logic between component geometric information and non-geometric attributes. The structural analysis and optimization period completes the lossless

geometric transfer of the BIM model to the analysis software, obtains indicator data such as inter-story drift ratios and component stress ratios through mode-superposition response spectrum calculation, and drives the iterative adjustment of cross-section dimensions based on the inversion results. The collaborative deepening and integration period performs hard collision and soft clearance collision detection in a multi-disciplinary integrated environment, and generates the hole positioning drawing and the detailed rebar arrangement drawing of joints according to the conflict resolution results^[5].

The BIM task-driven organizational procedure takes the complete deliverables of a typical structural system as the longitudinal guiding clue, transforms the stage teaching objectives into serialized engineering sub-tasks, and clarifies the input conditions and output standards for each node. Each sub-task is accompanied by a deliverable list matching the model depth of that stage, covering key outcomes such as component library merging files, cyclic mode analysis reports, and coordinated hole positioning plans. The stage transition nodes embed an automatic data compliance review rule set to perform a full scan for model overlap interference, missing material definitions, and cross-section type invocation errors. Models that fail the verification cannot proceed to the next stage, thereby constructing a progressive control closed loop based on data quality gates.

3.2 Preset Architecture of the Digital Teaching Resource Cluster and Collaborative Work Platform

The digital teaching resource cluster adopts a bottom-up layered architecture, which is sequentially divided into the basic component-level resource library, the typical case-level resource library, and the standard code-level resource library. The basic component-level resource library contains parametric component families of three major categories: concrete, steel, and composite structures, with each family type preset with a shared parameter set conforming to the rules of plane drawing expression. The typical case-level resource library selects four system types: frame, shear wall, frame-core tube, and large-span space grid, and configures complete data evolution snapshots from the scheme comparison model to the detailed design solid reinforcement model, while archiving the parameter change trajectories of key design nodes in a version chain format. The standard code-level resource library integrates normative information such as seismic design parameters, minimum reinforcement ratio limits, and construction detail drawing indexes through structured data tables, and establishes a real-time invocation channel with the BIM modeling environment via an interface.

The preset architecture of the collaborative work platform relies on a cloud-based central database to achieve hierarchical permission management. Its core components include a model storage server, a lightweight browsing engine, and an annotation tracking system. The model storage server divides independent workspace areas according to teaching groups and deploys incremental transmission protocols to reduce bandwidth consumption during concurrent operations. The lightweight browsing engine provides seamless model roaming and sectioning view access capabilities on mobile terminals. The annotation tracking system records the complete workflow of issue reporting, responsibility assignment, and status closure, and archives it in the model metadata. The platform presets a unified data exchange interface to be compatible with mainstream analysis software specifications, ensuring semantic consistency of geometric topological information and load case combination information during the round-trip transmission process.

3.3 Evolution Trend of Teaching Interaction Behaviors and Planning of Adaptive Guidance Strategies

The interaction behaviors in the BIM teaching environment present a significant evolutionary characteristic: they shift from model creation-oriented operational interaction to data analysis and collaborative decision-making-oriented analytical interaction. In the early stage of teaching, the interactions focus on modeling operations such as component selection, spatial positioning, and parameter input. As the process progresses, they gradually turn to boundary condition debugging, visual interpretation of analysis results, and observation of parameter sensitivity across multiple schemes. The interaction complexity further increases in the collaborative integration stage. Learners need to identify conflict sources in multi-disciplinary superimposed views, evaluate the cascading impact range of adjustment plans, and complete the closed-loop transmission of coordination instructions through the platform annotation system. At this stage, the nature of interaction has transformed into comprehensive training in the control logic of engineering information flow.

The adaptive guidance strategy is configured with differentiation based on the dynamic identification of the evolution patterns of interaction behaviors. In the basic modeling stage,

high-frequency structured demonstrations and operation flow replays are applied to reduce the initial cognitive resistance of three-dimensional parametric modeling. In the structural analysis stage, the guidance focus shifts to problem-diagnostic prompts triggered by computational divergence or indicator exceedance, thereby maintaining the learner's exploratory tension. In the collaborative integration stage, the guidance places greater emphasis on process control at the metacognitive level, focusing on the construction of priority frameworks for hierarchical conflict resolution and the training of identifying propagation delays in information changes. The core of the adaptive mechanism lies in the dynamic floating of intervention thresholds. The system automatically adjusts the level of detail of prompts and the timing of intervention based on the distribution of error types and the frequency of corrections in task deliverables, thereby maintaining the optimal driving force gradient for cognitive development.

Conclusion

The teaching mode for the building structure course based on BIM technology establishes the parametric three-dimensional model as the sole data source for teaching information flow, thereby realizing a dimensional leap in the structural cognitive path from discrete verification to systematic collaborative decision-making. This mode takes the hierarchical resetting of teaching objectives oriented toward structural cognition and collaborative analysis as its logical starting point, relies on the BIM data integration mechanism to complete the modular deconstruction and progressive ordering of teaching content, and builds a closed loop of cognitive construction and efficacy diagnosis through the integrated design of visualization-based interactive methods and a multi-dimensional evaluation mechanism. At the implementation level, the stage division of the teaching process and the task-driven organizational procedure, the preset architecture of the digital resource cluster, and the dynamic configuration of adaptive guidance strategies together constitute the supporting framework for the implementation of this mode. Future research can be advanced along two dimensions: the first is the quantitative characterization of the matching gradient between the information depth of the BIM model and the learner's cognitive development curve; the second is the deep integration of artificial intelligence-assisted model compliance verification and the adaptive feedback mechanism, so as to achieve higher-precision personalized learning path navigation and intervention responses in the structural teaching scenario.

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