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## Post-print: Application of BIM Technology in the Hechuan Qu River Landscape Bridge

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### Abstract

The Hechuan Qujiang Landscape Bridge adopts a single-main-cable earth-anchored suspension bridge with a main span of 400m. The bridge tower features complex curved surface modeling, and the main girder is a variable-width separated flat steel box girder. To improve design efficiency and ensure design quality, a “R+GH+R” BIM collaborative design platform is proposed. Through secondary development, information exchange between different software platforms is achieved, with built-in modeling standards and a component coding system, applying BIM technology for the entire bridge design. During the design process, technologies such as parametric batch modeling, real-time rendering, intelligent drawing generation, virtual reality, 3D printing, and 4D construction models are employed, enhancing design quality and work efficiency, while also accumulating experience for the development and application practice of three-dimensional bridge design.

### Full Text

#### Preamble

#### **BIM Technology Application in Hechuan Qujiang Landscape Bridge**

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**Abstract:** The Hechuan Qujiang Landscape Bridge employs a single-main-cable earth-anchored suspension bridge with a 400 m main span. Featuring complex curved pylon geometry and a variable-width separated flat steel box girder, this project necessitated a novel “R+GH+R” BIM collaborative design platform to enhance design efficiency and ensure quality. Through secondary development, information exchange between different software platforms was achieved,

incorporating built-in modeling standards and component coding systems to facilitate comprehensive bridge design using BIM technology. The design process leveraged advanced techniques including parametric batch modeling, real-time rendering, intelligent drawing generation, virtual reality, 3D printing, and 4D construction modeling. These innovations improved both design quality and workflow efficiency while accumulating valuable experience for the development and practical application of three-dimensional bridge design.

**Keywords:** single-main-cable earth-anchored suspension bridge; parameterization; real-time rendering; BIM technology

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## 1.1 Project Overview

The Hechuan Qujiang Landscape Bridge is situated 800 m upstream of the Qukou River mouth in Hechuan District, Chongqing, connecting the Yunmen area with the Diaoyucheng Peninsula. Designed to accommodate motor vehicles, non-motorized traffic, and pedestrians, it serves as a crucial river-crossing corridor for the Qukang Greenway Project [1]. Considering navigation requirements and topographical constraints on both banks, the bridge adopts a single-main-cable earth-anchored suspension configuration with a span arrangement of 130 m + 400 m + 146 m. The main cable sag-to-span ratio is 1/9, with a single deck width of 8.5 m [2]. The general layout is illustrated in [Figure 1: see original paper], while the overall perspective view is shown in [Figure 2: see original paper].

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## 1.2 Engineering Characteristics and Challenges

Compared with conventional bridges, this project exhibits distinctive technical features summarized in . The pylon employs a curved triangular arch form, the girder consists of a separated variable-width steel box, the cable system uses partially inclined hangers, the south bank features a gravity anchorage, and the north bank utilizes a tunnel anchorage. To meet these demanding design requirements, BIM technology was adopted from the initial design phase for the entire bridge.

The pylon design draws inspiration from “mountain ranges,” presenting clean, fluid lines and an aesthetically pleasing form. The middle and upper shaft profiles follow cubic parabolic curves, while the lower shaft uses straight segments. To minimize transverse bending moments on the pylon caused by temperature loads in the lower crossbeam, a discontinuity was introduced at the pylon centerline with a hinged connection. The unique curved geometry requires continuously varying cross-sections along the elevation, making BIM technology essential for accurate pylon modeling.

The main bridge stiffening girder adopts a separated flat steel box with a significant longitudinal gradient, comprising both curved and straight segments in plan. To enhance pedestrian safety and riding comfort, non-motorized lanes and walkways are separated from motor vehicle traffic, with the steel main girders connected through variable-width steel cross beams.

The cable system employs a single main cable with partially inclined hangers, with seven pairs of inclined hangers installed near each pylon. During construction, the main girder must be assembled segment by segment from the pylon side toward midspan to ensure adequate torsional stiffness under eccentric loading.

The north bank mountain geology consists primarily of interbedded sandstone and mudstone with relatively good surrounding rock stability. Considering construction cost, excavation volume, environmental impact, and aesthetic effects, a tunnel anchorage was selected.

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## 2 BIM Application Environment

### 2.1 R+GH+R Collaborative Bridge Design Platform

Given the bridge's unique curved pylon geometry and complex spatial positioning of main cables and girders, the BIM collaborative platform required robust surface modeling and precise geometric control capabilities. Additionally, extensive interdisciplinary coordination was necessary during design. The platform integrates three leading software systems: Rhinoceros (Rhino) for 3D modeling, Grasshopper (GH) for parametric design, and Revit for information integration. This combination leverages their respective strengths in form generation, development flexibility, lightweight operation, and high parametric efficiency while ensuring seamless information transfer and interoperability.

The resulting “R+GH+R” bridge BIM collaborative design platform establishes a comprehensive workflow, as shown in [Figure 3: see original paper]. The collaborative process operates as follows: (1) During conceptual design, Rhino and GH enable parametric adjustment and form exploration, providing real-time visualization for efficient communication and decision-making; (2) GH defines a “reference control line” for the bridge's central axis to precisely position piers, pylons, girder segments, and anchorages; (3) Based on the parametric skeleton model, Revit integrates multidisciplinary models and batch-assigns non-geometric information such as materials and reinforcement ratios to components, enabling interdisciplinary collaboration and information sharing.

### 2.2 Hardware and Software Environment

The BIM platform utilizes Rhinoceros, a professional 3D modeling software developed by Robert McNeel & Associates, as its geometric core. This is complemented by independently developed bridge design assistance systems R-BRG

and G-BRG, and integrated with Revit, Vray, Lumion, Fuzor, Midas, Abaqus, and other software to achieve information transfer and model interaction between platforms, supporting both 3D model and 2D drawing generation.

Hardware configuration includes high-memory, high-performance graphics workstations combined with advanced cloud computing technology, enabling rapid access to international cloud supercomputing clusters for intelligent online collaboration and cloud-based rendering (see [Figure 4: see original paper]). This infrastructure can handle complex computational scenarios and enables structural topology optimization, significantly enhancing design efficiency.

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### 3 BIM Design and Analysis

#### 3.1 BIM Model Construction

During the initial information modeling phase, modeling and delivery standards were established according to relevant regulations [3-4]. The bridge model was decomposed and managed collaboratively by category. Modeling principles and a component coding system were defined, as shown in [Figure 5: see original paper], enabling designers from different disciplines to work under unified guidelines and ensuring efficient model assembly.

The bridge information modeling workflow proceeds as follows: (1) Using parametric design software GH, a real-time adjustable bridge skeleton model is established to create an interactive platform between Rhino and Revit for batch-driving component families; (2) For conventional components, a comprehensive enterprise-level parametric bridge component library with adjustable parameters is utilized, as shown in [Figure 6: see original paper], enabling rapid modeling through batch parameter assignment; (3) For irregular structures, adaptive families are employed with parametric geometric control information to accurately model spatially complex geometries; (4) Based on the parametric skeleton model, positioning information is batch-assigned to components, which are assembled following the sequence of substructure, superstructure, and appurtenances to complete the geometric model; (5) Non-geometric information such as reinforcement ratios and materials is batch-added to components; (6) Multi-disciplinary models including mechanical, electrical, piping, and lighting systems are integrated into the bridge BIM model to enable interdisciplinary collaboration and meet BIM application requirements.

#### 3.2 BIM Model Applications

During the conceptual design phase, independently developed R-BRG and G-BRG design tools, combined with GIS geographic data, rapidly establish topographic models of the bridge site and surrounding environment while recording basic project information for effective management. Parametric tools enable rapid scheme iteration and optimization, while adaptive intelligent rendering

technology allows designers to conveniently adjust and visualize designs in real time, significantly enhancing creativity, evaluation, and decision-making efficiency in early stages, as shown in [Figure 7: see original paper].

During the design phase, the BIM model assists in three-dimensional design of complex nodes and enables first-person inspection of internal structural rationality and operational space accessibility to ensure constructability. Clash detection functions prevent soft and hard collisions in structural arrangements. Engineering quantity statistics performed within the BIM platform address the traditional challenges of errors and verification difficulties in 2D design. For drawing generation, BIM models provide intuitive three-dimensional views of complex nodes, and parametric design tools enable batch conversion of 3D BIM information models into 2D drawings meeting construction drawing requirements, achieving over 70% drawing efficiency for the irregular pylon structure.

For structural analysis, the parametric skeleton model rapidly generates three-dimensional frame finite element models in Midas through MCT command streams, enabling one-click execution and result verification [5], as well as rapid structural iteration and optimization. For areas with complex stress states, the BIM model directly interfaces with solid finite element analysis for mechanical simulation. Specific applications are detailed in .

During the design review stage, reviewers can intuitively examine structural safety and rationality based on the integrated BIM model, annotate problematic details within the platform, and link issues to specific components. In approved models, annotated components are highlighted, enabling designers to quickly identify and locate problematic elements, call Revit information models within the platform, and adjust designs according to review comments. The modified models automatically update in the BIM platform, making the review process more intuitive and efficient.

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## 4.1 Specialized Customization and Secondary Development

Throughout the project design process, customized secondary development for bridges was implemented based on the “R+GH+R” collaborative platform, covering conceptual design, preliminary analysis, and construction drawing phases, as shown in [Figure 8: see original paper].

**Part 1: R-BRG** focuses on secondary development for the conceptual design phase, including: (1) Intelligent integrated simulation of road traffic facilities and urban/natural environments, encompassing vehicles, pedestrians, vegetation, buildings, and traffic signs; (2) Standardization of modeling environments including line types, colors, and layers, allowing users to quickly switch and adjust settings according to design requirements; (3) Parametric random vehicle and crowd modules for rapid dynamic simulation of bridge pedestrians and traffic facilities; (4) Lightweight modeling of bridge appurtenances with quick

switching between railing, guardrail, and post configurations. The model and scene can be viewed in real time to evaluate scheme effects.

**Part 2: G-BRG** targets secondary development for the bridge design phase, encompassing rapid construction of main bridge and substructure models, parametric modeling and batch drawing generation for various bridge component families, automated reinforcement drawing generation through parametric methods, and rapid interaction with analysis models. This forms a complete set of lightweight, standardized, and automated 3D design workflows.

#### 4.2 VR Virtual Reality Technology Application

Virtual reality technology, centered on information technology, creates a simulated world of multi-source information fusion and interactive 3D dynamic visualization in a computer digital environment, enabling users to interact with virtual objects through visual, auditory, and tactile perception [6]. With advances in computer information technology, VR has found applications in bridge engineering. During this project's design, BIM+VR technology helped designers accurately grasp spatial scales of components while enhancing intuitive information interaction and transfer. The VR experience process is illustrated in [Figure 9: see original paper].

#### 4.3 3D Printing Technology

Based on BIM models, 3D printing technology uses environmentally friendly polylactic acid (PLA) material and layer-by-layer printing to construct geometries [7], offering advantages including low cost for complex forms, no secondary assembly requirement, simple operation, environmental friendliness, and high model precision. This project employed 3D printing technology for pylon shape refinement and optimization, ultimately determining the final pylon configuration, as shown in [Figure 10: see original paper]. To facilitate future construction, the pylon side surfaces were designed with single curvature to enable reusable formwork, reducing construction costs.

#### 4.4 3D Visualization for Construction Technical Briefing

Given the construction complexity of this bridge, BIM-based 3D visualization was employed for construction technical briefing to help participants intuitively understand the entire construction process. Compared with traditional 2D briefings, this approach enables more accurate comprehension of key construction sequences and allows contractors to further refine construction steps based on the model and organizational measures, serving the BIM model for the construction phase. Construction process simulation is shown in [Figure 11: see original paper].

## Conclusion

This paper presents the design methodology and practical application of BIM technology in the Hechuan Qujiang Landscape Bridge design phase, proposing an “R+GH+R” bridge design collaborative platform characterized by strong modeling capabilities, development flexibility, lightweight operation, high parametric efficiency, and effective collaboration. Customized secondary development within the platform enables information exchange between different software systems, providing efficient solutions for bridge BIM implementation. This project pioneered intuitive design review and approval processes within the BIM information platform, further leveraging BIM’s application value. However, integrating BIM design-phase outcomes with construction and operation-maintenance phases requires further investigation. This paper aims to provide new insights for BIM application in bridge design.

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