

3D Road Modeling Method Based on CATIA Software (Postprint)

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Abstract

CATIA, as a powerful three-dimensional collaborative design software, has been widely applied in the field of water conservancy and hydropower engineering. The design of access roads and on-site construction roads constitutes an important component of three-dimensional collaborative design for water conservancy and hydropower engineering projects. Based on the modeling of access roads for a specific hydropower station project, this paper introduces a method for establishing three-dimensional road models using CATIA software, which builds upon two-dimensional planar design achievements.

Full Text

Introduction

Water conservancy and hydropower projects are characterized by large investment scales, long design and construction cycles, numerous participating disciplines, and complex system structures. To improve design efficiency and standards while enhancing core competitiveness, the water conservancy and hydropower design industry is gradually transitioning from traditional 2D planar design to multi-disciplinary 3D collaborative design. In such projects, access roads, construction roads, and camp roads connect the entire construction area, making 3D modeling of roads an essential component of a complete project design. Compared with conventional planar design that relies solely on 2D horizontal, vertical, and cross-sectional data to express the spatial structure and location of roads, 3D design offers higher precision and more intuitive visual results.

Currently, several software packages are available for road 3D modeling, including CARD/1 from German company IB&T, AutoCAD Civil 3D from American Autodesk, CATIA from French Dassault Systèmes, Weidi Road Design Software from Xi'an Jingtian Transportation Engineering Technology Research Institute,

EICAD from Nanjing Dinuo Technology, and Roadleader from Hongye Technology. While CARD/1, Weidi, EICAD, and Hongye can generate road 3D models and produce drawings and tables, their capabilities in parametric associative design and terrain surface processing are limited, failing to meet the requirements of multi-disciplinary collaborative design for large and complex projects such as water conservancy and hydropower works. AutoCAD Civil 3D is a professional 3D design software capable of completing road engineering, drainage network system, and site planning designs. Its road modeling function can combine horizontal and vertical geometry with customized cross-section components to create parametrically defined dynamic 3D models for highways and other transportation systems. However, it requires integration with other software for building models and mechanical-electrical assembly designs, presenting shortcomings in the 3D design of general construction layouts for water conservancy and hydropower projects.

CATIA is a large-scale, high-end CAD/CAE/CAM integrated design software developed by Dassault Systèmes of France. It integrates geology, engineering structures, construction layout, site transportation, metal structures, and mechanical-electrical assembly for water conservancy and hydropower engineering 3D design. Through its collaborative design platform VPM, it transforms fragmented individual designs into centralized online design, enabling effective management of design models, structures, skeletons, parameters, and associative information. CATIA features powerful parametric design capabilities and comprehensive knowledge engineering functions, allowing the establishment of universal template libraries for road cross-sections and ancillary structures to achieve knowledge reuse and model associative updates. Due to its numerous advantages in multi-disciplinary collaborative design and road 3D modeling for water conservancy and hydropower projects, CATIA has been widely applied in the overall design of such projects.

Based on the access road modeling in a domestic hydropower project 3D collaborative design, this paper introduces a method and workflow for establishing road 3D models using CATIA software, built upon the design results from 2D road design software.

CATIA Road 3D Model Design Process

The design process comprises the following steps:

1. Collect basic road design data, including terrain and geological information, as well as 2D planar design results such as road alignment, longitudinal profile, stake coordinate tables, and standard roadbed cross-sections.
2. Establish a 3D solid terrain model based on terrain data.
3. Create the road centerline in the CATIA 3D terrain model according to 2D planar design results. This centerline is a spatial curve.
4. Develop a 3D parametric template for the roadbed cross-section, with

parametric settings for roadbed width, slope gradients, slope height, and berms to facilitate invocation and modification.

5. In the CATIA Generative Shape Design interface, utilize the roadbed cross-section template along the road centerline to establish the roadbed outline surface model for the entire route.
6. Perform intersection operations between the roadbed outline surface model and the 3D terrain solid model to generate road fill and cut bodies, as well as the modified 3D terrain solid model after excavation and backfilling.
7. Establish 3D models for road ancillary structures such as ditches and guardrails on the terrain solid model after road excavation and backfilling to obtain a complete road 3D model.
8. Utilize CATIA' s quantity calculation function to statistics roadbed fill volume, excavation volume, and quantities of various ancillary structures for cross-checking with calculations from 2D design software.

Road 3D Model Establishment

3.1 Basic Principles The world coordinate system adopts the right-hand Cartesian coordinate system, with the XY plane as the horizontal plane and the Z direction as the elevation direction. Modeling units are unified throughout the project.

3.2 Terrain 3D Model Establishment In CATIA, terrain models can be established using the software' s own mesh modeling and editing functions, or by importing terrain model files created by other software. Several commonly used methods for CATIA terrain model establishment are described below.

One approach involves importing point cloud data generated from topographic contour lines provided by surveying departments to create a 3D terrain mesh model. Alternatively, 3D geological models can be built using geological software such as GOCAD, with TS, STL, or 3DMAX format files then imported into CATIA to generate terrain models. Another method employs GIS software like ArcGIS to establish a digital terrain model, converting ArcGIS' s TIN model files into STL format for import into CATIA to generate terrain models.

The 3D solid terrain model is obtained by performing Boolean operations between the CATIA-generated 3D terrain surface model and a cuboid solid model of the same scope. This 3D terrain solid model precisely positions the entire water conservancy and hydropower project hub and prepares for foundation filling and excavation of roads, dams, and other structures, ultimately forming a complete 3D model of the project hub together with various engineering structures.

3.3 Route Establishment A road is a three-dimensional spatial band entity whose center is defined by the road centerline. The spatial position of the road

centerline constitutes the route, which is a spatial curve. In CATIA, routes can be established primarily through two methods.

The first method generates routes directly from spatial points. Based on 2D road design software results—namely, the road stake coordinate table and roadbed design table—numerous three-dimensional point coordinates (X, Y, Z) are obtained from the route start point along the alignment to the end point. In CATIA, spatial coordinate points are sequentially established using these 3D coordinates, or coordinate sequences for road alignment points are imported from external Excel files to obtain spatial points. These points are then connected in order from the route start to end using spline curves to obtain the route. This method is simple to implement but requires inputting numerous spatial points for long routes, and the route simulated by connecting points with spline curves lacks high precision.

The second method involves importing and synthesizing 2D curves. This approach imports the road horizontal curve and vertical profile generated by 2D road design software into CATIA to create the route through extrusion, development, and development transfer commands. First, the route start point is established, and the road horizontal curve in DWG or DXF format is imported and extruded along the Z-axis (road elevation direction) to obtain an extruded surface, which is then developed. Next, the road vertical profile is imported onto the developed surface, and the development transfer command is applied to obtain a spatial curve on the extruded surface—this curve is the design route. Although more complex than the direct spatial point method, this approach synthesizes the route from two 2D curves (horizontal curve and vertical profile), ensuring both alignment and elevation completely match the actual design with high precision. The route model in CATIA is shown in Figure 1 [Figure 1: see original paper].

3.4 Standard Cross-section Parametric Model The road cross-section refers to the normal plane at any point along the road centerline, consisting of the cross-section design line and ground line. Typical roadbed cross-section forms can be summarized into three types: embankment, cutting, and half-fill half-cut. Roadbed cross-section shapes mainly include trapezoidal (straight-line), broken-line, and stepped with berm types. The standard cross-section designed for this project is the stepped type, including both roadbed excavation and filling cross-sections. For convenient inspection and modification of the roadbed cross-section design scheme, the roadbed cross-section outline is parameterized, including pavement width, roadbed fill slope, excavation slope, slope height, and berm width. The road standard cross-section outline model is shown in Figure 2 [Figure 2: see original paper].

3.5 Roadbed and Pavement 3D Model Establishment In CATIA, roadbed 3D solid models are primarily established through Boolean intersection operations. This involves creating a roadbed 3D mesh or standard outline

surface (or roadbed standard 3D solid) and performing Boolean intersection operations with the established terrain surface (or terrain solid) model to obtain the CATIA 3D model of the roadbed structure. The steps for establishing CATIA roadbed 3D models are briefly described below.

First, establish and parameterize the road standard cross-section outline model at the road start point. Next, use the sweep command to extend the road standard cross-section outline along the entire route to obtain the full-section standard outline surface (excluding the start and end face profiles). Then, create the start and end roadbed standard cross-sections and join them with the full-section standard outline surface lacking the end faces to obtain a complete, closed full-section roadbed standard outline surface model.

Subsequently, convert the fill roadbed standard outline surface model into a solid model using the embed command. Perform Boolean operations between this solid model and the terrain surface—the roadbed 3D solid above the terrain surface constitutes the roadbed fill 3D solid model, as shown in Figure 3 [Figure 3: see original paper]. Use the cut roadbed standard outline surface as a cutting surface to cut the terrain solid—the terrain 3D solid above the cutting surface becomes the road cut body, while the terrain solid below becomes the post-excavation terrain 3D solid. The roadbed 3D model after excavation and backfilling is shown in Figure 4 [Figure 4: see original paper].

To create the pavement structure model, extract the top surface of the roadbed standard outline surface using the multiple extraction command and form a thick surface consistent with the pavement design thickness—this thick surface is the pavement structure model.

3.6 Quantity Calculation During the road 3D design process, 3D solid design models for terrain excavation bodies, road fill bodies, ditches, guardrails, and other elements are placed in corresponding geometric bodies. CATIA's volume measurement tools can then be used to statistics excavation volume, fill volume, and quantities of various ancillary structures. These results can be cross-checked with quantities calculated by 2D road design software such as Weidi or Haidi.

Advantages and Limitations of CATIA in Road Design

CATIA software features powerful knowledge engineering and parametric modeling functions. Utilizing CATIA to establish road 3D models in the water conservancy and hydropower engineering domain not only completes the 3D design of the entire project hub but also provides more intuitive understanding of road alignments and roadbed conditions along access roads, construction roads, and camp roads. Practice demonstrates that the method described in this paper enables quick and accurate establishment of road 3D simulation models based on 2D planar design results in CATIA. This method is applicable to road model establishment in all CATIA-based 3D collaborative design projects for water

conservancy, hydropower, wind power, and other infrastructure projects.

In the overall design of large and complex engineering projects, using CATIA to establish road models offers the following advantages: (1) it enables the entire design process from terrain model establishment and road 3D modeling to 2D drawing generation and quantity calculation; (2) it facilitates multi-disciplinary online collaborative design on the same platform with real-time model updates and multi-disciplinary data sharing, allowing collaborative work without mutual interference and significantly improving design efficiency while shortening design cycles; (3) when arranging roads in project hub areas, it conveniently checks for interference and collisions between routes and other disciplines, substantially reducing design errors; (4) benefiting from excellent parametric design and knowledge engineering functions, parametric templates for road cross-sections and ancillary structures can be established in CATIA for convenient modification by designers and invocation in other projects; (5) terrain, road horizontal, vertical, and cross-sectional data are interconnected with 3D models, enabling synchronous model updates for any parameter modification and greatly reducing model modification workload during design changes; (6) through the VPM platform, design, verification, and review processes can be completed simultaneously, with reviewers able to browse road models in real-time via the network to identify issues promptly and reduce designer modification workload; and (7) it possesses powerful terrain surface processing capabilities for establishing accurate terrain models, enabling more precise calculation of road excavation and backfill quantities.

However, CATIA software also presents certain limitations in road design. For instance, the software currently lacks a dedicated road engineering design module and cannot apply existing standards and specifications directly for design. Direct road 3D modeling in CATIA would require substantial design verification workload, necessitating integration with professional road design software results to quickly establish specification-compliant road 3D models. Additionally, when route designs are excessively long, increased data volume may cause slow program operation. We anticipate that subsequent CATIA versions will further expand spatial applications to make greater contributions to engineering construction.

References

- [1] Huang Shaohua, Wan Jun, Wang Jinfeng. Application of CATIA Software in Road 3D Dynamic Planning and Design[J]. Yangtze River, 2014, 45(14): 61-63.
- [2] Miao Zhengjian, Wang Shudong. 3D Design of General Construction Layout for Water Conservancy and Hydropower Projects Based on Civil 3D[J]. Yangtze River, 2015, 46(Supplement I): 137-138.
- [3] Wang Jinfeng, Li Xiaoshuai, Fu Youjie. Application of CATIA Software in 3D Collaborative Design of Hydropower Projects[J]. Yangtze River, 2009, 40(4): 68-70.

- [4] Wang Qiuming, Hu Ruihua. Research on Key Technologies of 3D Geological Modeling Based on CATIA[J]. Yangtze River, 2011, 42(22): 76-78.
- [5] Liu Chao, Yang Jinqiang, Li Jianrong. Application of CATIA in 3D Geological Modeling[J]. Modern Mining, 2012, (3): 40-41.
- [6] Deng Xuejun. Subgrade and Pavement Engineering (Second Edition)[M]. Beijing: China Communications Press, 2005.

Abstract: As a powerful 3D collaborative design software, CATIA has been widely used in the field of water conservancy and hydropower engineering. The design of access roads and construction roads is an important part of the 3D collaborative design of water conservancy and hydropower engineering. According to the access road modeling of a Hydropower Station, this paper introduces a method of building 3D road model by using CATIA software, which is based on the results of two-dimensional design.

Key Words: CATIA; Road; 3D Model; Water Conservancy and Hydropower Engineering; Parameterize

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

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