Hydraulic and Civil Engineering Technology VII
M. Yang et al. (Eds.)

doi:10.3233/ATDE220864

Research on Application of BIM Technology in Bridge Health Monitoring

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Abstract. In order to improve the intelligent level of man-machine interaction and auxiliary decision, this paper takes a bridge as the engineering background, selects box girder, pier, cap, pile foundation and so on to carry out parametric modeling. The secondary development process of Revit was explored. Based on IFC framework, Revit API functions were used to expand the data dimension of Revit. To make the bridge health inspection system redundant data visualization, to present the effect of real-time data model, can more intuitively understand the health of the bridge, the bridge disease status to make real-time diagnosis, early warning, and put forward the disposal countermeasures. Through the analysis of the model and data, the influence of the bridge under different climate conditions can be understood, so as to work out the most suitable bridge management and maintenance plan, increase the work efficiency in the operation and maintenance stage, and reduce the waste of funds.

Keywords. BIM, parametric model, application programming interface, health monitoring system, bridge management and maintenance

1. Introduction

Application of BIM technology can help to realize the integration of the information architecture, from building design, construction and operation until the end of the whole life cycle of buildings, all kinds of information is always combine in a 3 d model database, the design team, construction units, facilities operating department and the owner all staff can be based on BIM to work together, Effectively improve work efficiency, save resources, reduce costs, in order to achieve sustainable development. The concept of BIM was first proposed in the 1970s and entered China in 2005. Since 2008, Shanghai Center, the landmark building of Shanghai, decided to adopt BIM technology in this project, and the development of BIM technology in China began to accelerate. In 2011, China's first BIM research center (Huazhong University of Science and Technology) emerged. The development of BIM in the bridge field started later. Due to the complexity of bridge structure and the variation of component surface, BIM modeling of bridge is more difficult. Traditional bridge detection relies on the experience of managers and technicians to a large extent, and lacks scientific and

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systematic methods. Therefore, it often lacks a comprehensive grasp and understanding of the bridge, especially the condition of large Bridges, and the information can not be timely feedback. This paper aims to study how to combine the model produced by BIM software with the bridge health information monitoring system, solve the compatibility problem between modeling software and analysis software, and make up for the deficiency of traditional bridge management and maintenance mode [1-3].

2. Establishment of Parametric BIM Model

2.1. Engineering Situations

Baijianhe Bridge (shown in figures 1- 12), a high-pier long-span continuous high-pier long-span continuous rigid frame bridge with the span arrangement of (75+2×135+ 75)m, is located in the section from Taiyuan to Macao expressway Jiyuan to Jincheng (provincial boundary).

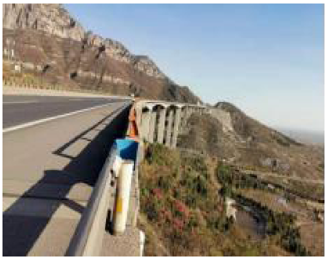

Figure 1. Bridge layout.

Figure 2. Thin-walled pier.

2.2. Modeling of Main Components

The bridge components are divided systematically, and the modeling process is introduced respectively [4]. Then, the plane geometric relationship of the components is bound by the bridge center line to facilitate the positioning of the bridge components and form the whole bridge. The key of Revit parameterization is to draw the reference plane, constraint the contour to the reference plane and customize the name and size.

Metric structural frame-beam and support family model was used for modeling. Reference elevation view was selected, and two bridge members were created to support a family. First, the reference plane was created. In the horizontal direction, the reference surface of the pile cap is set as the reference elevation, and the reference surface of the pile foundation is the bottom of the pile cap, so that the structural relationship between pile foundation and cushion will not change due to the change of parameters [5].

Table 1. Family type parameters indication.

Parameter	The numerical
Structural materials (default)	
Width of pile caps	1120.0
Length of pile caps	1120.0
Height of pile caps	400.0
The pile x	150.0

The pile y	150.0
Pile diameter	180.0
Pile length	2500.0

Since the foundation slab is a cube, the reference plane is set up to surround it into a rectangle. Use stretch to draw the appropriate model lines to create 3D solid shapes. Use the same method to create the reference plane in the front elevation view, mark the dimensions and create a parameter, which is the foundation slab height. Enter the specific size values and load them into the project, as shown in table 1.

The reference elevation view is selected to establish the reference plane, and the circular line is drawn as the outline of the pile. Mark and create parameters for pile diameter. Create size parameters between piles and define them as pile spacing b and pile spacing h. Create adaptive parameters of pile edge distance b and pile edge distance h. Use the following formula:

$$\text{Pile edge distance b} =$$

$$(\text{Pile cap length} - \text{Pile spacing b} * 2 - \text{Pile diameter}) * 0.5 \qquad (1)$$

$$\text{Pile edge distance b} =$$

$$(\text{Pile cap width} - \text{Pile spacing h} * 2 - \text{Pile diameter}) * 0.5 \qquad (2)$$

Select the front elevation view and establish a reference plane under the foundation slab. Dimensional mark is made from the distance from the bottom of the cap to the reference plane, and the parameter is the pile length. Dimensions and models are shown in figure 3 and figure 4.

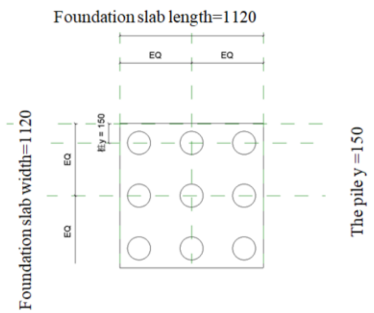

Figure 3. Reference elevation view of pile cap and pile foundation.

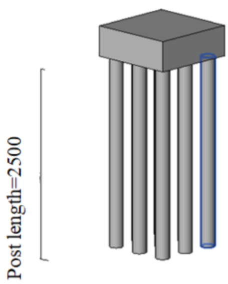

Figure 4. Three-dimensional model of pile cap and pile foundation.

2.2.1. Parametric Modeling of Bridge Pier Family

Create a reference plane in the reference elevation view so that the distance from the reference plane to the edge of the cap is 110 and 235 respectively. Create a reference plane to mark each dimension of the hollow and parameterize it. Use the hollow stretch command to draw the hollow outline on the base of the pier. At this time, hollow stretching cannot create hollow graphics on the view because there is no corresponding topological relationship established. It is necessary to manually select two graphic components and click Cut to complete the creation of hollow bridge piers. Elevation view and 3D model after cutting are shown in figure 5 and figure 6.

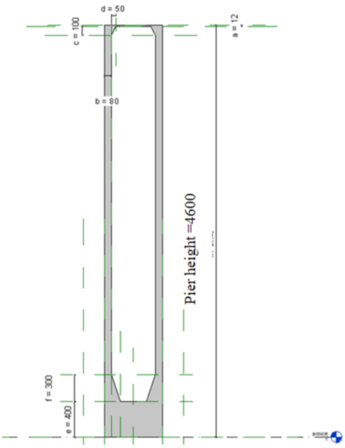

Figure 5. Front elevation view of pier.

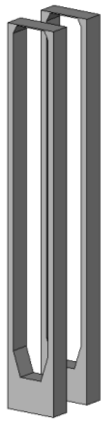

Figure 6. Three-dimensional model of bridge pier.

2.2.2. Parametric Modeling of Box Girder Family

The parametric model of beam family is carried out by selecting the frame-beam family model of metric structure. Two parameters, starting elevation displacement and ending elevation displacement, can be provided by the beam model, so that the longitudinal elevation change can be easily controlled and the deflection can be easily displayed. In addition, the rotation Angle parameter of the beam section can control the transverse rotation Angle of the bridge and the transverse slope of the bridge effectively. Parameter design of variable cross-section box girder is mainly realized through dimension constraints and geometric dimension constraints. The specific steps are as follows.

Step 1. Create a new metric contour family, draw the outer contour with lines, and add labels to get the parameters. The main parameters are beam height, floor width, roof width, etc, which are saved as section 1 and loaded into the project, as shown in figure 7. For the drawing of the outer contour of section 2, the copy command can be used to enter the new contour family, and the parameters can be modified in the new contour family to quickly draw the outer contour. The drawing method of the inner contour is similar to that of the outer contour in figure 8.

Step 2. After loading, the loaded contour family in the project browser is seen. Click the lofting fusion command and draw the path. Then, selection contour 1,2 corresponding to section 1,2 respectively. The outer outline of the box girder has been built. The correlation family parameters can be used to model the specific parameters. The standard box girder block is shown in figure 9.

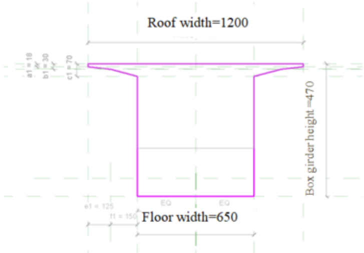

Figure 7. Outer contour 1.

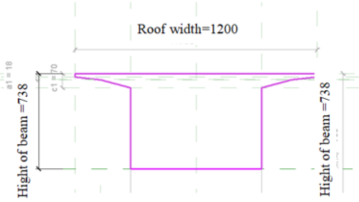

Figure 8. Outer contour 2.

Step 3. The final step is to debug the added parameters. The overall three-dimensional graph of the bridge is shown in figure 10, and the main bridge is shown in figure 11.

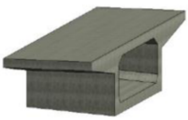

Figure 9. Standard block of box girder.

Figure 10. Overall 3D model of the bridge.

Figure 11. Three-dimensional model of main bridge.

3. Application of BIM Model in Health Monitoring System

3.1. Use Excel Tables to Drive Family Parameters

There are two main data-driven methods for family parameters. One is to use data files to drive the parameters, and the other is to drive the data directly by placing the data in the type of the family. To create the category of family parameter types, it is necessary to make the parameters of the Excel table first [6]. The parameters contained in the table are roughly shown in table 2. Segmented by #, the first part is the custom parameter name. The parameter name must match the parameter name in the model. The second part is about parameter types. The type syntax needs to be written according to the official syntax of Revit, such as LENGTH## LENGTH##, material ##OTHER##, VOLUME##, etc., otherwise Revit will not recognize the contents of the table 2. The third part is the units of parameters.

Table 2. Examples of parameter types supported in the Revit software type catalog.

Parameter type	Parameter declarations	annotation
Text	param_name##OTHER##	
Integer	param_name##OTHER##	
Number	param_name##OTHER##	
Length	param_name##LENGTH##FEET	
Area	param_name##AREA##SQUARE_FEET	
Volume	param_name##VOLUME##CUBIC_FEET	
Angle	param_name##ANGLE##DEGREES	

Slope	param_name##SLOPE##SLOPE_DEGREES	
Currency	param_name##CURRENCY##	
URL	param_name##OTHER##	
Material	param_name##OTHER##	
Yes/no	param_name##OTHER##	Defined as 1 or 0
< family type >	param_name##OTHER##	Family name: type name without file extension
Original data parameters:		
Annotation mark	Keynote##OTHER##	
Parts code	Assembly Code##OTHER##	
Type annotation	Type Comments##OTHER##	

Save the excel table in csv format, open it with the computer's own notebook software, and save it as text in txt format. When saving, the text name should be consistent with the name of the family, and the family file and parameter file should be saved under the same path. Then it is loaded into the project test. At this time, Revit will appear a type directory to automatically generate box girder family instances [7]. The family instances are drawn according to the bridge center line.

3.2. Data Processing of Bridge Health Monitoring System Platform

Figure 12 for the transverse displacement of the structure of deployment diagram of measuring points, measuring point 4, for example, the station is in the left main bridge location. Real-time data can be exported excel spreadsheet as shown in table 3. In the position of the measuring point 4 model, add control point coordinates x, y, z to import the form to the Revit model. The coordinate offsets in y direction to represent the lateral displacement of the structure of the bridge [8].

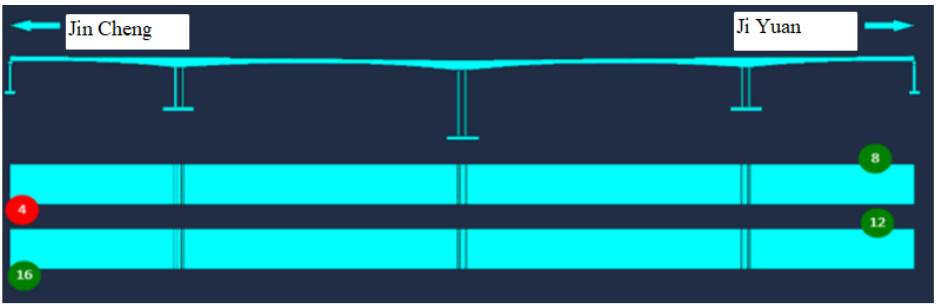

Figure 12. Position of measuring points for bridge lateral displacement.

Table 3. Lateral displacement data in a certain period.

Number	Time	Maximum	Minimum	Average
1	2021/5/12 11:28	-5.78	-5.86	-5.81358
2	2021/5/12 11:29	-5.68	-5.86	-5.80262
3	2021/5/12 11:30	-5.76	-5.86	-5.80669
4	2021/5/12 11:31	-5.76	-5.86	-5.79817

5	2021/5/12 11:32	-5.78	-5.86	-5.80815
6	2021/5/12 11:33	-5.76	-5.86	-5.80135
7	2021/5/12 11:34	-5.76	-5.86	-5.80712
8	2021/5/12 11:35	-5.76	-5.86	-5.79721
9	2021/5/12 11:36	-5.76	-5.86	-5.80418

Figure 13 is the dynamic deflection measurement point diagram of main girder. The data of each measurement point are made into Excel form and imported into the control points of Revit model, so that multiple data can be made into a visual model, which can carry the deflection information of the bridge.

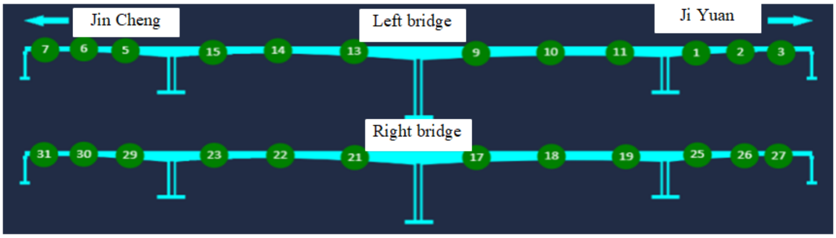

Figure 13. Position of deflection measurement points of bridge.

3.3. Feasibility Analysis of BIM Information Management

It is very tedious to monitor the state of the bridge according to the method of 3.2 to make the deformation visualization. The application of BIM information management can build a "bridge" between the model and the data. The coding and mapping relations are re-formulated to establish the connection between BIM and the management function [9]. In the current BIM application, the expansion of BIM data dimension is mainly realized through the expansion of IFC (Industry Foundation Classes).IFC is open BIM data expressing and exchange standard. IFC standard is an object-oriented data model system, which can describe real physical objects [10]. The overall framework of IFC is layered and modular, which is divided into four layers from top to bottom: domain layer, sharing layer, core layer and resource layer. Each layer contains many modules, and each module realizes the management and sharing of information resources respectively, as shown in table 4.

Table 4. IFC data schema architecture.

Layer	Module
Field layer	Architecture; Structure; Electric; Fire-fighting domain; Structural; HVAC; Bridge; Tunnel; Railway
Sharing layer	Building sharing; Terrain sharing; Building sharing; Equipment sharing; Management sharing
Core layer	Control expansion; Product expansion; Process expansion
Resource layer	Data and time; Geometric constraint; External reference; Geometric model; Geometry; Material; Manpower; Attribute; Cost; Tool; Outline; Geographic information; The topology; Apparent expression; Audit; Structural load; Description; Construction organization; Quantity; Performance

4. Conclusion

BIM technology can make the bridge health monitoring information visualization. The main research achievement of this paper is to apply BIM technology to the health monitoring of Bridges. Based on the IFC framework, the API function is used to carry out the secondary development of Revit, so that it can communicate with the bridge health monitoring data platform database, so as to make the bridge visualization and informatization. Bridge in the model of visual information, managers can very easily get the target data, understand the status of the bridge health, through the contrast of Bridges under different environment data, a targeted formulate follow-up maintenance plan, also facilitate the smooth implementation of the repair work, improve the custody of the intelligent human-computer interaction and auxiliary decision-making level.

Acknowledgments

In the research of this paper, we thank the fund Shandong Province Transportation Science and Technology Plan (2022B79) for providing us with financial and technical support. Without them, this paper would not be completed. I would like to express my thanks to them again.

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