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Development and application of BIM-based highway construction management platform

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ABSTRACT: Building Information Modeling (BIM) covers most of the information of a construction project, and becomes a powerful for construction management nowadays. In this paper, a BIM-based highway construction management platform was established. There are mainly three part in this platform, including data management, data updating and query. High-precision images from QuickBird were taken as the main data source. SQL server database was used to manage all the construction data. GIS was then applied as a tool to integrate all the functions together. The platform was then applied on a part of the Jinghua highway. It is shown that a construction management platform established based on BIM concept could make the construction more efficient and effective.

1 INTRODUCTION

The concept of Building Information Modeling (BIM), also named Building Product Models (Eastman 1999), was first clearly presented by Bernsteinand Bhatt. This concept was then broadly accepted by engineers. It creates and applies digital models to help the project management in the whole life circle of a building, including design, construction and operation. To achieve this, BIM integrates all kinds of information for the building into a digitalized system.

Study on the BIM standard gains more and more attentions after advantages over 10 year. In 1991, Industry Alliance for Interoperability (IAI) released the first full version of Industry Foundation Classes. In 2006, a practical BIM standard was proposed based on IFC in USA, named by National Building Information Model Standard (US National Institute of Building Sciences Facilities Information Council, BIM Committee 2006). According to newly released version of NBIMS in 2007, a BIM defines the cumulative, shared knowledge resource containing many different kinds of information from many different application platforms (US National Institute of Building Sciences Facilities Information Council, BIM Committee 2007). The definition could be logical, physical or virtual for the life cycle of a facility.

Because of the ability to efficiently manage and control the project process, BIM is widely applied in the construction of many kinds of facilities, especially highway.

The total length of highway in China is now about 74,000 km. Furthermore, the total length is planned to 108,000 km by 2015. So it is obvious that lots of highway need to be built from now on. Under this condition, it is necessary to make the highway construction more efficient.

In this paper, a BIM-based platform for the highway construction management is established, with the support of Service-Oriented Architecture (SOA) andweb services. The integrated platform was then applied in actual construction management processof a highway in China. It is shown that the platform established in this paper could be a helpful tool forhighway construction.

2 BASIC STRUCTURE

Construction of a highway is a kind of comprehensive project. It could be subdivided into many units, including bridges, tunnels, slope cuttings and fillings, foundations and pavements, and some attachments like drainage, slope protection and the service area, etc.

Compared with other facilities such as public buildings and hydropower station, highway is more like a line carrying traffics. So the modeling of highway construction is quite simpler than other facilities. We do not need to make the digital model so fine to identify all the details of a specific attachment.

Considering what kind of information we need to know to manage the highway construction, and what kind of function need to be realize to support the management, a brief structure of BIM-based highway construction management platform is presented here, shown in Figure 1.

There are mainly three levels in this basic structure.

(1) Persons level categorized people into mainly five groups, including owners, designers, constructors, supervisors, and operators.
(2) Phrases level mainly deals with timing. It covers all those work related with construction, such as survey, design, testing, and monitoring.

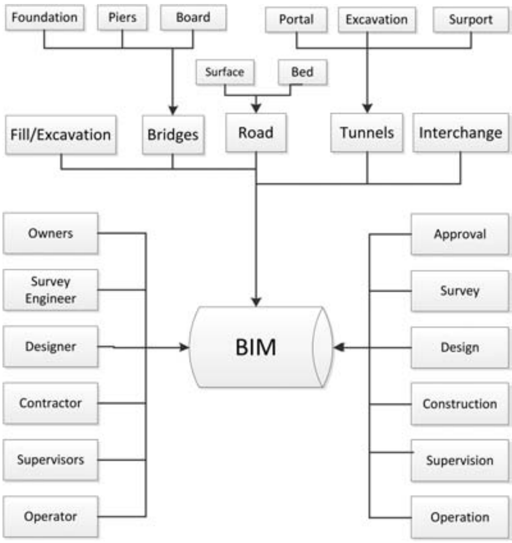

Figure 1. Structure for BIM-based highway construction management platform.

(3) Construction units level covers the units in highway construction, including bridges, tunnels, roadbed, pavement, slope protections, and so on. According to the characteristics of highway, construction could be subdivided into units mentioned above. Different unit might be constructed by different contractors. In this way, construction of the highway could be also managed by unit. For example, the schedule of each unit could be controlled separately.

3 DEVELOPMENT

Based on the above three-leveled structure, a simple platform for highway construction management is established here. The main data structure and function of this platform is illustrated in Figure 2.

To overcome the shortcoming of traditional management method, BIM integrate all the information needed into a digitalized system, shown in Figure 2. As for highway construction, data like geology, topography, transportation, building facilities along the highway are necessary.These are environmental parameters. Besides, the design data for facilities, as well as the construction information like real schedule of a unit, are directly used to describe the construction itself.

This system is not static. On the opposite side, the system must be open or dynamic so that any change differs from plan could be considered. In another words, the system must grow up or update dynamically as it does in reality.

Before the construction of a highway, there are already many roads along it, which makes it inevitable to pass through those roads built already. From this

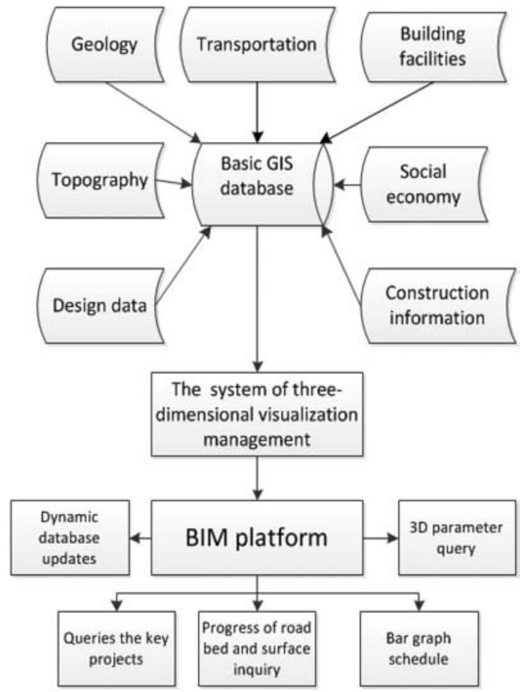

Figure 2. Data and function design of a simple BIM-based highway construction management platform.

aspect, three-dimensional visualization seems critical for efficient construction management.

To achieve the management ability using this platform, basic query functions such as query about detailed three-dimensional parameters of some units need to be included. Furthermore, schedule management for each unit construction is also necessary. In this paper, simple bar graph is used to describe the construction schedule.

4 APPLICATION

Based on all the above consideration, a simple platform was established and applied on the construction management of one part of a highway in Hebei province, China.This part ofhighway is designed to connectTumu and Jiaoniwan.

The route is roughly 72 kmlong, with 25 super major bridges, 4 tunnels, and 100 grade separations.

4.1 *Data source*

Quickbrid satellite images along the highway with high precision were firstly gathered. Afterbeing preprocessed and adjusted, they are merged with the digital elevation model (DEM). By this way, three-dimensional image for the study area was successfully created, as shown in Figure 3.

Other data, such as traffic, facilities, and CAD files for design, are transformed after importing into

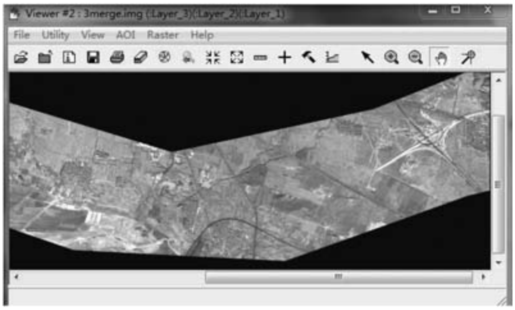

Figure 3. Quickbird satellite images for study area.

Figure 4. GIS database of highway construction.

a geodatabase. The raw data usually stores in dwg format. Using ArcGIS, data in dwg format is transformed into shp format by layers. The vector data is shown in Figure 4.

4.2 *Data management*

In design stage of the platform, basic data, such as the geological and topological information, is static and could be managed with GIS. Other attribute data, such as the schedule information input by constructor with web, is dynamic and is not suitable to be managed with GIS. Here SQL server was selected as the dynamic data management tool. So actually, a hybrid data management system is utilized, with both ArcGIS and SQL server, shown in Figure 5.

Different person were authorized to mainly two types, i.e. constructors and managers. Constructors input the schedule information in reality, and they could only read those data that they charges. Managers could read, query, and analyze all the schedule information.

4.3 *3D Visualization*

Three-dimensional visualization is realized using Skyline, as shown in Figure 6. Three-dimensional query could be easily performed by this GUI. In order to make the management more efficient, in-situ photos taken at real time are updated by constructors, so that managers could check by simply click on the links, as shown in Figure 7.

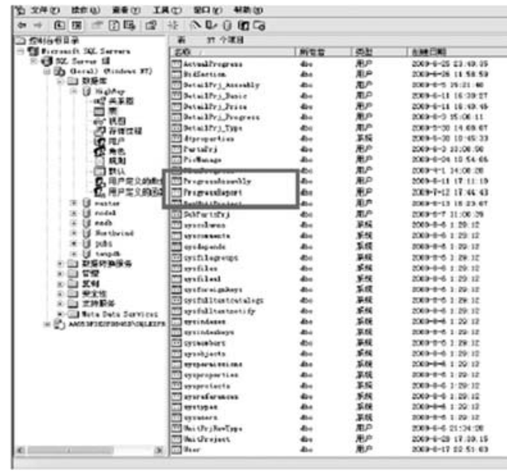

Figure 5. Data management.

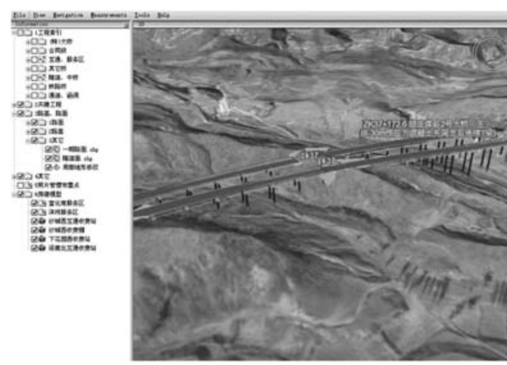

Figure 6. 3D visualization.

Figure 7. In site photos taken at real time.

4.4 *Construction schedule management*

To manage the construction schedule, basic information should be updated dynamically. Here, an input interface for constructors is supplied as shown in Figure 8.

Based on the schedule information stored in the database, managers could query and analysis tasks. As shown in Figure 9, the construction of a bridge is divided into many levels of subunits. The manager

Figure 8. Schedule information input GUI for constructors.

Figure 9. Query about the construction schedule of a bridge.

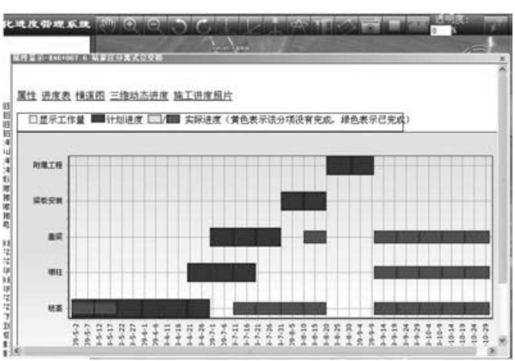

Figure 10. Schedule of a unit construction.

could easily query and check the construction through this interface. To analyze whether the schedule is left behind or not, or which part of the unit is left behind, Gantt chart is used here, as shown in Figure 10.

5 CONCLUSION

A simplified BIM-based highway construction management platform was established, withQuickbird satellite images and DEM. Three-dimensional visualization, construction schedule input, query and analysis could be easily performed by this plat form. The platform was then applied on one part of the Jinghua highway construction management. It is shown that the platform could be a helpful tool to make the construction management more efficient and effective.

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The study of casing collapse deformation for slump fault

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ABSTRACT: The research presented attempts to simulate the tectonic stress field distributions by inverting the actual well logging and by establishing the finite element model of structural fault. Since the earthquakes can lead to abrupt change instantaneously of tectonic stress field, slump fault could be simulated owing to abrupt change stresses inside the tectonic stress field by increasing edge loading instantaneously in the two opposite side of the field. Sliding on fault can result in casing collapse deformation. So the quantity analyses between the rock formation slippage and the casing strength were conducted. Meanwhile, the influence of casing load was analyzed by simulating parallel wellbore fault and shear casing fault. From a new aspect, the paper investigated the impact of the tectonic stress field due to the earthquake and then analyzed its influences on the casing collapse deformation. It shown that this method is applicable and effective for casing strength design.

1 INTRODUCTION

Qunkuqiake structural zone is located in Taxinan depressed area of Tarim basin, where the earthquake frequently occurs. During the process of India plate being propelled toward north, the changes of structure load were reflected by the increasing of pressures of Taxinan in close-north and close-south. There is a huge Bashituopu faulted zone in the south of Qunkuqiake structural zone. Therefore, some slump faults will be emerged due to the seismic activity, which causes the sliding of the formations along different directions and consequently leads to the casing collapse. This problem brings serious damage to casing security (Yang et al. 2000, Zeng et al. 2007, Sone et al. 2005, Zhou & Yang 2005).

2 INVERSION OF STRUCTURE STRESS FIELD BY USING FINITE ELEMENT

The task of the study was to obtain the collectable actual measured stress data of studied wells on the field and to utilize finite element method to invert the stress distribution in the whole field (Cristescu 1991, Chan & Bodner 1992).

2.1 *Elastic principal equation*

Elasticity variables are displacement, stress and strain. The variables need to satisfy the geometry equation Eq. (1), the balance equation Eq. (2), and the constitutive equation Eq. (3) as follows.

$$\varepsilon_{ij} = \frac{1}{2}(u_{i,j} + u_{j,i}) \quad (1)$$

$$\sigma_{ij,j} + f_i = 0 \quad (2)$$

$$\sigma_{ij} = \lambda \varepsilon_{kk} \delta_{ij} + 2\mu \varepsilon_{ij} \quad (3)$$

where, $\sigma_{ij}, \varepsilon_{ij}, u_i, f_i$ represent stress tensor component, strain tensor component, displacement tensor component, and volume vector respectively. δ_{ij} is Kroeneker delta. While $i = j$, $\delta_{ij} = 1$; and $i \neq j$, $\delta_{ij} = 0$. λ and μ are Lame's constant.

According to the actual measured stress data and engineering geology condition in the studied field, the field was idealized as a complete elastomer and the medium of all rock formations were isotropy in order to find out the distribution pattern of stress. To acquire the stress in the filed by using the method of inversion, that was to invert the magnitude and the direction of stress in the field with given magnitude and directions at several measuring point.

2.2 *Establishment of finite element model*

Tectonic force was assumed to be horizontal orientated in a real two-dimensional model and applied on the border of calculated field. Fixed constraint was applied on the point of left bottom corner of the model, and normal direction constraint on the points of left upper corner and right bottom corner of the model. Tectonic force was loaded on the four borders of the model. Sixteen loading coefficient was applied, as shown in Figure 1.

2.3 *Objective function optimization*

Assume the actual measured magnitude of stress and calculated finite element for n well holes are available, the minimum residual sum of square was (Szczepanik