BIM Process and Application in Geological Exploration of Rail Transit Engineering in Mountainous Cities

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Abstract. Based on the practical problems in the geological modeling of rail transit engineering in Chongqing, this study conducts a comparative analysis of the commonly use methods of engineering geological modeling. In view of the special geological conditions such as sand-mudstone interbedding and lens in mountainous cities, the problem of unified stratification of complex strata is solved by means of three-dimensional auxiliary layering and a process of three-dimensional modeling suitable for regular underground running tunnels and deep-buried underground running tunnels in mountainous cities is established.

1. Introduction
BIM (Building Information Modeling) has innovated the traditional design methods in the architecture industry. After more than 10 years of development and popularization, BIM Technology has been gradually introduced into the field of infrastructure. In light of Chongqing’s mountainous environment, undulating terrain, and complex geological conditions, rail transit construction is facing the challenge of crossing rivers, mountains and ridges. Most of them are located in hidden underground spaces and are linearly distributed. They are in close contact with geological information. So the construction has to deal with the challenge of the complex geological environment and allocating resources in a narrow space. In the traditional geotechnical engineering survey and design, the expression of engineering is mainly in the form of two-dimensional information. For the complex geological structure of underground space, the expression is relatively more abstract. There are some problems such as poor information transmission, unclear expression of geological intents, uneven deployment of resources, and abstract display of results. BIM Technology can more directly reflect the terrain, strata, geological structure and other conditions so that the geological conditions can be truly digitally displayed, with geological information, and can be used in the design, construction and operation and maintenance stages of Chongqing rail transit[1-4].

Given the complex geological conditions featured by faulted fold development and undulating terrain in Chongqing City, using the traditional engineering geological methods, combined with modern geological information and spatial information technology, as well as the existing data of remote sensing, geophysical exploration, drilling, pipeline, oblique photography, a three-dimensional geological information model of urban rail transit in mountainous area is established. The model incorporates ground city information and underground tunnel information, thus overcoming the complex geological structure of mountainous cities. A complete set of rail transit survey BIM establishment and delivery route is constructed, and the integrated display and application of multi-source data are carried out. The model can significantly improve the work efficiency in the
design and construction stages, provide geological information guarantee for rail transit construction, promote the informatization construction of rail transit throughout the stages of survey, design, construction, operation, maintenance and management, and provide important support for the construction of smart cities, prevention and control of urban geological disasters, planning management, engineering design and construction.

2. Engineering Geological Modeling Method
Through the layout of indoor survey scheme, based on the integrated system of geotechnical office work and field work, digital field collection, indoor two-dimensional automatic mapping and three-dimensional geological modeling, combined with multi-source heterogeneous data such as surface buildings, oblique photography, hydrology, remote sensing images, geographical base maps and underground pipelines, underground buildings, and physical and chemical properties of the strata, the seamless connection and integration of geometry, space and attribute is achieved and a new digital process of production investigation and delivery based on the 3-D geological model is established (Figure 1).

Figure 1. Project Technology Roadmap.
The basic working process of full digital engineering survey solution is as follows:

- **Scheme layout**: use Lizheng engineering geological survey software to arrange the survey scheme, and import the arranged drilling data into the integrated system of geotechnical office work and field work;
- **Field data import and auxiliary stratification**: after the field work is completed, the data collected through the field app will be imported into Lizheng engineering geological survey software, and the geotechnical trial data and terrain data collected will be imported into the survey software, and the 3-D layering tool will be used for layered numbering[5-6];
- **Generation of 2-D results**: use the survey software to automatically generate 2-D survey results charts, including plans, sections and column charts;
- **2-D results archiving and storage**: original survey data, regulatory data, results charts, reports and other 2-D results can be imported into Lizheng engineering geological database for data archiving for later query and use;
- **3-D geological modeling**: various pre-processing conditions generated by the 3-D layering tool of the survey software and stratum attribute information after statistical summary can be imported into Lizheng 3-D geological modeling software to establish 3-D geological models;
- **Delivery and integration of 3-D results**: the established 3-D geological model can be imported into Lizheng geotechnical Revit software, and integrated application can be carried out by combining the imported pipelines and Revit model for structures;
- **Integration and display of 3-D results**: for line engineering, the 3-D geological model and other related models of each construction site can be integrated and applied in Lizheng BIM integrated display software.

3. Example of Engineering Projects

3.1. Running Tunnel

The total length of the west extension section of Chongqing Rail Transit Line 4 is 11.15 km and has 9 stations, including 4 transfer stations which can transfer to Line 3, Line 5, Line 6, loop line, Line 21 and Line 23, respectively. The line passes through Ciqikou’s syncline, Shapingba’s anticline and Jin’aozi’s syncline. The line is long, and the surrounding structures and underground pipelines are widely distributed. The engineering importance level is Grade I; the environmental risk level is Grade I; and the engineering investigation grade is Grade A.

Using BIM Technology, the information construction and application of the whole process of engineering survey is completed, including data collection and storage, GIM modeling, model connection, multi-source data loading, engineering application and output of results. The seamless docking of station models and section models in space and attribute is realized.

- **Survey preparation stage**: Using the self-developed panoramic 3-D geographic information system (Figure 2), the virtual exploration of the surrounding environment of the proposed site can be realized, and use the existing regional geological model can be utilized to assist the drilling layout.
Field data collection and storage. The integrated system of geotechnical engineering investigation based on office work and field work is used to realize the standardized, intelligent and integrated management of project survey data collection. All field production data can be synchronized into the database, and the information of office work and field work can be seamlessly connected.

3-D modeling. A stratum model can be established by using the 3-D layering tool (Figure 3). The strata can be first divided in the 3-D environment, and then the results map and survey model can be generated. The layering tool is used in the form of section layering familiar to the survey engineer. Through the adjustment of the layer lines between the exploratory holes, the stratum grouping division and numbering of the site area are completed, and the stratigraphic composition framework of the engineering field area is established (Figure 4-7).
• Model connection. A new auxiliary section is built at the junction of the model, and the section is imported into the next segmented interval model to participate in the geological modeling of the next segment of the model, which can ensure the seamless connection of the geological models at the model junction (Figure 8).

• Multi-source data integration. According to the information of ground, underground and different spatial dimensions, using homologous and fine data, the 3-D geological model of urban underground engineering is combined with the surface terrain, structures (Figure 9), pipelines (Figure 10) and oblique photography models (Figure 11) to realize the connection and integration of spatial morphology, geometric information and attribute information. The BIM model of engineering investigation in the study area is thus established (Figure 12).
3.2. Mountainous Tunnels

The administrative division of Tieshanping-Ganbazi section of the rail transit line 4 phase II project is under the jurisdiction of Jiangbei District and Liangjiang New Area of Chongqing. The total length of the section is 5153.814 m, including tunnel, general subgrade and elevated section. The length of the tunnel section is 4147.517 m. The section passes through Tongluoxia’s anticline and is located in the isolated zone of Southeast Sichuan. The structural framework was formed in the late Yanshanian folding movement and crossed the Gaokanzi fault. There are large altitude differences between sections; and many exposed strata and local fracture zones are also developed. The importance level of the project is Grade I which is identified as the medium complex site, and the engineering investigation level is Grade A.

BIM Technology is employed in the project to complete the information construction and application of the whole process of engineering investigation. Based on the core algorithm of DSI (Discrete Smooth Interpolation), terrain model (Figure 13-14), overburden model, rock body model (Figure 15) and groundwater surface model of the site are constructed efficiently.

Based on the engineering GIM model, the visualization applications of model sectioning, attribute query, tunnel excavation (Figure 16) and workload statistics are completed, which are available for 2-D CAD drawing (Figure 17).
4. Summary
In view of the conditions of the steeply undulating terrain, faulted fold development and complex geological structure in Chongqing, this study establishes a process of geological modeling technology featured by high modeling accuracy, good detail and fast modeling speed through combing the traditional drilling and profile constraint modeling methods to overcome the over-development of sand-mudstone interbedding, spiral strata and lens and the complex landform in the target region, thus improving modeling efficiency. It has been proved by the application of multiple projects that the survey BIM model can help realize the forward design of BIM in the design stage and carry out parametric design, scheme optimization, construction drawing generation, and that it can even be combined with calculation models to achieve synchronous optimization. It can also effectively improve the efficiency in the design and construction stages, thus avoiding repetitive work. In addition, it can enhance the level of informatization and integration in the field of rail transit engineering.

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