

Application of BIM-based 5D construction technique to Chenglang Bridge

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Abstract. In connection with Ningbo Chenglang Bridge project's characteristics of complicated structure and mode, large horizontal scale, narrow construction yard, short construction period, etc., BIM technology is applied to direct construction of the project. Revit series software is applied to establish parametric model for Chenglang Bridge, and collision inspection, optimization of construction scheme, virtual construction and complicated process disclosure, etc. are finished. Through independent development of construction management platform, control on security, quality, and progress as well as cost are realized in bridge construction management. With satisfactory effect, the project provides reference for BIM application to like bridgework.

Chenglang Bridge project has complicated structure and mode, large horizontal scale, narrow construction yard, short construction period. In the former experience-dominated construction method, the construction course is uncontrollable, and construction result is indefinite, prone to causing hard-to-estimated losses, so this method cannot meet actual demand any longer. Applying BIM technology to conduct virtual construction for bridge construction course before construction can decrease accidents and improve engineering quality. Meanwhile, this can facilitate construction units' coordinating construction sequence of different specialties, organizing in advance professional squad to enter the site for construction, preparing equipment, site and turnover materials, etc. to actualize informatized, visualized and integrated management over construction yard, course and complicated construction procedure, achieve dynamic control ^[1] over labor service, physical resources and cost in construction course. The owners suggested application of BIM technology to serve the project's construction in early planning period of project, and it is required to constantly explore BIM related techniques in practice to solve difficulties in actual project. The paper adopts BIM technology to construct Chenglang Bridge, realizes overall planning of project, explores construction management experience of application of BIM technology in full life cycle of bridgework, excogitates a set of key BIM technologies suiting bridgework, and lays some foundation for BIM application to future bridgework.

Project profile

Chenglang Bridge is an important node project crossing Fenghua River in Ningbo municipal major project of Yongda road connection project. The total length is 446m, main bridge is 183m, main arch span is 175m and span width is 35m. As shown in figure 1, with no pier set in water,

Chenglang Bridge is a non-wind-support inward-inclined carbon steel arch rib arch bridge. The arch rib inclines inward by 10 degrees. The main bridge is half-through steel case arch bridge disposed using askew bridge. The approach span adopts prestressed concrete continuous box girder. The finished Chenglang Bridge will connect east and west section of Yongda road, link up Haishu district and Jiangdong district in Ningbo, thereby greatly improving south railway station's capacity of dispersing passengers flow, and facilitating traffic conversion in east railway station, south railway station, automobile passenger transport center and Lishe airport.



Figure 1. Effect drawing of Chenglang Bridge

Analysis on project charaters and challenges

(1) Main bridge's steel structure precast elements are in a large number. Installation procedure is complicated. The construction course is influenced by spatial location, large volume and heavy mass of members, crossing of construction machinery, etc. Organization and cooperation relationship of construction is complicated. Coordination is difficult and it is also quite difficult to establish construction organization scheme.

(2) Main bridge structure is half-through non-wind-support steel case arch rib arch bridge, which maintains own stability by inclining inward by 10° . In the course of hoisting arch rib, there are complicated construction yard and surrounding site environment such as bracket arrangement, and complicated operation radius of mechanical equipment, complicated jib length spatial position of member height, and the installation risks and challenges are large and hidden dangers for safe work practices exist.

(3) Construction period is tight, and the influence of tide, flood season and navigation requirements, etc. is significant. It is difficult to guarantee normal navigation of waterway during construction period. To control construction schedule is stressful

(4) The project is located in urban area, where the traffic road net around is complicated. The construction has significant influence on surrounding traffic. The construction site is narrow, and is limited by navigation clear height in down stream. The large floating crane cannot pass. Traditional construction yard floor plan cannot intuitively reflect dynamic procedure of construction, nor can it optimize management of materials, equipment and site.

Implementation of BIM technology on Chenglang Bridge

Virtual modeling

Use BIM modeling software to establish professional 3D parameterized model for each member of bridge and equipment, etc., conduct collaborative design based on one same coordinate system, plan spatial position, actualize accurate parametrized and visualized modeling. 3D model visually displays 3D effect model of each member of Chenglang bridge and related construction equipment, and furthermore realizes visualized management and query of model information. The information

model of Chenglang bridge is based on the core of BIM full life cycle management to lay the foundation for virtual construction in later stage. The frame of actualizing BIM technology is as shown in figure 2

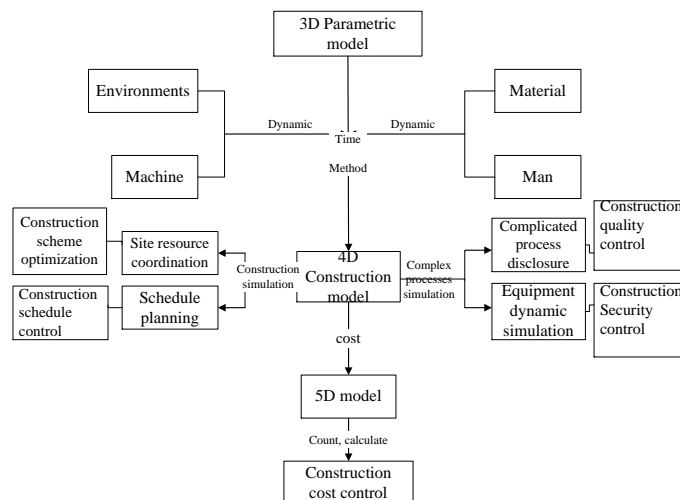


Figure 2. Frame of BIM-based virtual construction

4D construction simulation

Divide 3D model by member, and then relate time dimension and member in a parametrized way, build 4D information model. Simulate and display construction procedure and construction course of project according to construction organization plan, conduct comprehensive construction simulation in virtual environment, help the construction party to find out the problems in construction scheme, guarantee correct interprocess logical relation, lower risks caused by construction procedure.

(1) Establish 4D model

Utilize Navisworks Manage software to build BIM-based virtual construction platform, utilize Animator module to fabricate animation simulation of concrete construction scene, link it to TimeLiner simulation animation. Use TimeLiner module to link bridge's 3D model and construction schedule, integrate construction resources and site layout, etc. to build 4D model. BIM construction model maps overall process of construction scheme into a virtual environment, and observe, track, control and direct overall process of construction through operating this virtual environment, so as to verify, optimize, adjust and optimize construction scheme [2]

(2) Simulation of construction course

Use BIM 4D model on computer to realize dynamic simulation of construction process. The simulation process of bridge construction is mainly by following steps: divide simulation stages→formulate simulation schedule plan according to schedule plan in each stage→check model according to plan→establish temporary facilities and construction machinery submodel→export and import model→arrange set→import schedule plan and adhere the set→set simulation parameters→debugging and simulation→set camera waypoint→debug→export simulation [3]. Observe dynamic construction course from different viewpoints. Meanwhile, utilize TimeLiner module to add progress data and make them correspond to model, set relevant parameters, so as to generate construction course animation displayed with highly artificial 3d animation.

Information management system

Based on excellent extensible interface of Revit and Navisworks to develop Web-based BIM information management system. In construction course, make project information such as material, progress, quality, cost, etc. and BIM member interact. Realize model management, collision management, schedule control, quality control and security management

Application achievement of BIM technology to Chenglang Bridge

Collision inspection of comprehensive pipeline

Use Navisworks to make collision test for design model of Chenglang Bridge. After collision inspection of comprehensive pipeline, it is found that many places in pipeline collide. Figure 3 shows part of collision points of Chenglang Bridge. The designers made adjustment and optimization according to collision found, to prevent reworking and waste due to pipeline collision.

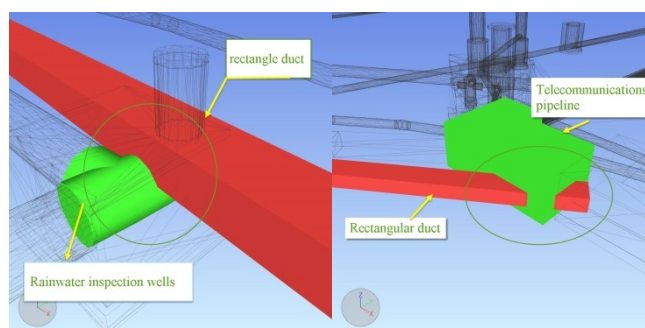


Figure 3. Collision test for comprehensive pipeline

Construction schedule control

Import BIM model of Chenglang Bridge and Microsoft Project scheduled plan into Navisworks software to simulate bridge's construction schedule plan, and conduct virtual construction, realize 4D schedule control^[4-5]. Inspect whether time parameters of scheduled plan is reasonable (i.e. whether duration of each work is reasonable, and whether logical relation between works is accurate, etc.) through BIM-based virtual construction technology, thereby inspecting and optimizing project's schedule plan^[6].

Meanwhile, after construction simulation using BIM model, find out the critical path and key mission, optimize key mission pertinently, so as to optimize general construction scheme of bridge, guarantee rationality of bridge construction sequence and proper linking of procedures, as well as balanced construction rhythm. In actual construction, the constructors can add time parameters of construction process to members, and manager can visually and quickly query and track site operation schedule through 4D schedule, look for the key point hindering progress, evaluate process flow, allocate resources. Part of schedule plan and image progress of Chenglang Bridge is as shown in figure 4.

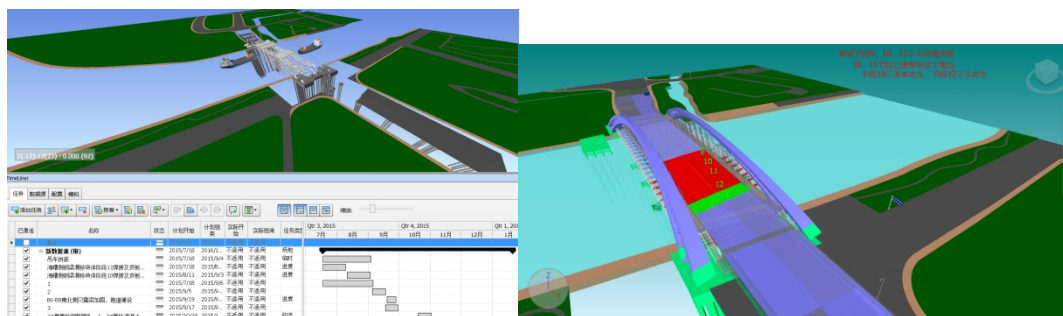


Figure 4. Construction schedule

4D schedule control directs project schedule planning. Meanwhile, in site management, the construction site's practical situation is reflected in model for variance analysis. According to model schedule analysis result, schedule control is optimized, and finally complete and effective construction course information is formed, and the course information is timely typed in information management platform to effectively conduct construction schedule management.

Construction security control

As arch rib segments of Chenglang Bridge are mostly difficult in installing, hoisting construction procedure and the situation in constructin site are complicated, and once mechanical equipment is found unable to meet construction requirements in later stage, it should be replaced, leading to delaying construction schedule and increase of cost, thus arc rib of Chenglang Bridge is simulated and construction scheme is evaluated and optimized.

(1)Equipment information model

Arch rib hoisting adopts two trunk cranes for double crane lifting. The requirements on installation exercise radius of arch rib and on lifting height should be met to avoid crossing and collision of construction machinery. Firstly, Revit software is applied to establish parameterized model of crane, define adopted crane's operation radius, jib length and lifting height, as shown in figure 5.

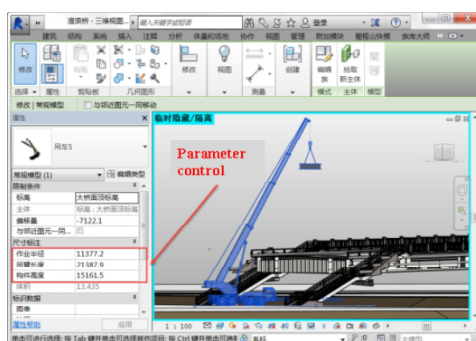


Figure 5 Parameterized model

(2)Arch rib installation construction simulation

Utilize Navisworks software to simulate arch rib installation construction. In this construction simulation process, control of parameters is most critical. This simulation figures out gyroradius, lifting height and lifting weight of crane in hoisting of each segment, and prevents collision or overturning of crane in construction course, thereby reducing installation risk. The lifting height of arch rib segment and operation scope of construction machinery are simulated in a refined way, and

whether march line of trunk crane collides with subsidiary construction facilities. Arch rib installation simulation is as shown in figure 6.

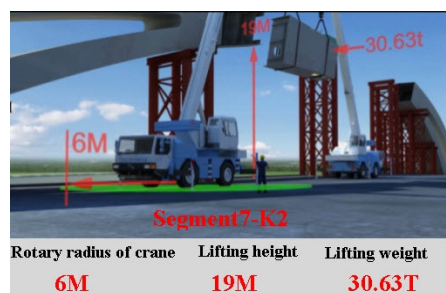


Figure 6. Simulation of arch rib installation procedure

Establishment of 4D construction model actualizes arch rib installation simulation, applies simulation result to direct construction, guarantees security in general construction course, reduces construction accidents, and further improves informatization of bridgework realm.

Construction quality control

Based on BIM construction information model to use animation rendering to display construction course, use BIM 360-glue technology to conduct visualized disclosure [6]. Make complicated spatial design and process flow more visual, enable constructors to understand design idea and construction scheme requirements more profoundly. Figure 7 presents the course of complicated procedure disclosure of Chenglang Bridge. The constructors utilized virtual construction achievement and accomplished desired objective fully.

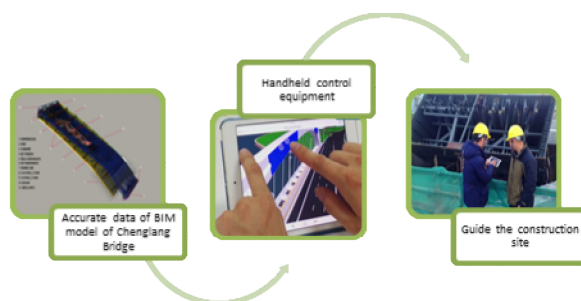


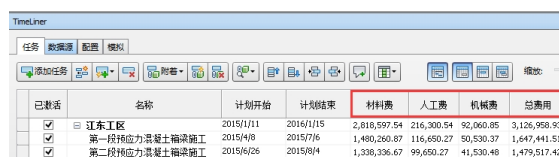
Figure 7. Complicated process disclosure

If problems occur in actual construction, they can be fed back to model to pinpoint the problem by comparing with original bridge model, which effectively eliminates the construction errors due to different reading of drawings or different understandings about drawings and norms by managers and workers, thereby improving production efficiency in construction site.

Construction cost control

5D construction management is to add cost control shaft based on 4D construction simulation, and in this course, relates engineering work load, material expenses, labour cost and other cost information to form BIM 5D model. In this module, model member is sorted according to list of engineering work load, and calculation and valuation are calculated according to calculation rule of engineering work load, then multiple calculations comparison is conducted. BIM technology is combined to calculate engineering work load and cost. Based on 5D model, construction resources are deployed in a refined way, and materials supply and demand plan are optimized. As shown in figure 8, the approach span construction stage for Chenglang Bridge is simulated and calculated. The

approach span's original five-stage placement is optimized into two-stage placement. Compared with original plan, the construction period is saved by about 10 days, and engineering material cost is saved by about 100,000 Yuan. Total project cost is saved by about 120,000 Yuan. Figure 8 is schedule - cost control plan optimized by Navisworks



已激活	名称	计划开始	计划结束	材料费	人工费	机械费	总费用
<input checked="" type="checkbox"/>	辽东工区	2015/1/11	2016/1/15	2,818,597.54	216,300.54	92,060.85	3,126,958.93
<input checked="" type="checkbox"/>	第一段预应力混凝土箱梁施工	2015/4/8	2015/7/6	1,480,260.87	116,650.27	50,530.37	1,647,441.51
<input checked="" type="checkbox"/>	第二段预应力混凝土箱梁施工	2015/8/26	2015/8/4	1,338,336.67	99,650.27	41,530.48	1,479,517.42

Figure 8. Schedule - cost control plan

To sum up, applying BIM technology realizes integrated and dynamic management of construction schedule, cost resource, quality, security and site; coordinates construction organization schemes of different specialties, combines construction simulation to optimize construction in real time; realizes reasonably utilization of site, avoids crossing operation, decreases or even avoids reworking; improves use rate of construction machinery, reduce double handling of materials, reduces construction cost and saves expenditure and construction period, thereby laying a solid foundation for directing actual construction.

Conclusion and envisagement

Conclusion

The paper displays some achievements made by applying BIM technology to construction practice of Chenglang Bridge.

(1) Build construction optimization information model, link 3D model with construction schedule, integrate 3D model with construction resources and yard layout information, actualize 4D dynamic integrated management of construction schedule, manpower, materials, equipment and yard layout and 4D visualized simulation of construction process.

(2) Simulate overall construction process for Chenglang Bridge, design construction scheme of complicated procedure, formulate construction schedule and construction scheme, generate construction simulation animation and complicated procedure disclosure, directly apply virtual construction achievement to directing of construction of Chenglang Bridge, and provide scientific and reliable reference for construction management.

(3) Applying BIM-based virtual construction technique in Chenglang Bridge project saved 32 days for total project duration, and 385,000 Yuan for overall cost, and realized security, high quality, progress and cost control.

Envisagement

Currently the research emphasis is on application of BIM technology to design and construction stage of Chenglang Bridge. The BIM technology is smoothly carried out in Chenglang Bridge project, and successfully directs actual project, and is of milestone significance for application and generalization of Ningbo bridgework BIM technology. However, the theoretical investigation and practice of BIM technology in construction course of Chenglang Bridge project is still at the exploration stage, and more application and research needs to be delved into. The future exploration content can be application of BIM technology to bridge's operation management, stress and linear monitoring.

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