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Research on the Application of Building Information Model Technology in the Design of Urban Residential Buildings in Cold Region

Rui Han[1*], Yueqiu Gao[1] and Dan Shao[2]

[1]*College of Art, Jilin Jianzhu University, Changchun 130118, China*
[2]*College of Computer Science and Technology, Changchun University, Changchun 130022, China*
48987515@qq.com

Abstract

The design of urban residential buildings in cold region is different from that in low latitude region, or the design of general public buildings. The precise grasp of dwelling unit type and appearance style, effective control of building heating and thermal insulation efficiency and the implementation of the sustainable concept of low cost construction and environmental protection are dependent on the early scientific and rational design. And the building information model technology just acts as a platform for the optimization of the design. The study is based on the engineering projects; the planning, the design of building facade, collision detection optimization and the full participation of construction cost control in building information model provide a new train of thoughts and research reference for the residential design in cold region, in the context of the digital age, and to a certain extent, the study looks forward to the future urban residential design and construction industrialization prospect in the cold region . Building information modeling technology improves the design efficiency and quality with its precise data processing and analysis, avoids the defects in design and the material waste of construction and environment pollution, significantly enhancing the pre-processing level of construction structure parts, which is in line with the energy-saving environmental protection and rural environmental construction philosophy advocated by the state, and the green building strategies of sustainable development.

Keywords*: Building information model, Cold region; Sustainability, Urban residential design, Collision detection*

1. Introduction

As the industrial base of new China, the three provinces of Northeast China are located in the cold region of high latitude; the revival cannot be achieved without the talents. The construction of high quality residential buildings is not only an important issue to improve the people's livelihood, but also an important guarantee for the harmonious development of the economy in Northeast China. In order to adapt to the development of the new situation, it is needed to make the urban residential design of the cold region be more and more sustainable. The building information model technology can better optimize the design plan, reduce construction costs, and improve the efficiency of building maintenance. The case study is based on the Dayu Brown Stone Park Residential Project in Changchun City; it is intended to introduce building information model technology from the perspective of the residential life cycle, integrate single building planning, plane and facade design, construction cost accounting and other pre construction processes, make full use of the powerful functions of multi professional collaborative production design of information model, construction effectiveness analysis, and collision detection, so as to establish a new model of an urban residential design in cold regions, and provide a more suitable living environment for house

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owners, further optimize the spatial structure and management pattern of urban and rural areas in northeast old industrial base and enhance the comprehensive bearing capacity of the cities[1].

2. Research Significance

The cities in cold region refer to the cities which have a negative impact on urban life because of the long winter and harsh climate, and the length of the average temperature with 0 degree in a year is more than three months. Special geographical location determines the unique natural climate characteristics of urban cold regions, the smaller solar altitude angle leads to the short duration of bright sunshine, winter days are short and the nights are long and accompanied by a lot of snow, while the temperature of summer is moderate and rainfall is less. The location of the project in the study case is Changchun City, its central city is located in north latitude of 43 ° 05 ', belongs to the typical city in cold region. The research on the energy-saving optimization design of its residential is of great significance for regional saving energy and resource depletion, reducing pollutant emissions and creating comfortable life environment.

In recent years, with the extensive application of building information modeling technology in the field of construction engineering, the design quality is constantly improving, and information models have participated in the important construction projects of large and medium-sized cities in the country. The information data transmission has integrated the architectural design, structural design, equipment design, energy efficiency analysis, construction control and digital maintenance as a whole, greatly enhancing the design efficiency and construction efficiency [2]. For the urban residential building design with higher standards in cold regions under the new situation in the new era, the technology can better optimize building structure, improve the insulation efficiency of building wall, control the cost of construction, improve the operation and maintenance level of the buildings in cold regions, which is in line with the demands for sustainable development advocated by the state, as well as the development strategy of green building, energy conservation and emission reduction [3].

3. Research Status at Home and Abroad

Most of the developed countries in the world are located in the high latitude regions, and the cities in cold regions are widely distributed in cold regions such as North America and Northern Europe. Since ancient times, people in these areas have accumulated rich experience in building construction in the process of fighting against the harsh natural conditions, and designed a lot of harmoniously developed residential buildings which are symbiotic and harmonious with the environment [4].With the development of the theories and practice of urban design, the outbreak of the world energy crisis in 1973in particular caused people to re-evaluate the architecture and urban design of decades. Especially in the cities of cold regions, the environment supported by consuming a large number of cheap energy and a variety of technical design in the past has been greatly negatively evaluated. Since then, the energy saving technology of single building has been rapidly developed. In the eighties of the last century, people have realized that only from the single building level, especially the material and structural measures cannot solve all the problems. They began to understand and grasp the urban architectural design in the cities of cold regions from the binary level of the micro and macro urban environment. Since new millennium, a series of theoretical research and practical exploration have been carried out by various countries located in the cold regions of high latitude according to their own development and the characteristics of the natural and regional environment, and has achieved fruitful results [5].

Developed countries in northern Europe such as Denmark, Sweden, Finland, Norway, have developed rapidly in construction technology because of social policy stability, national

wealth accumulation. The active thoughts of architecture complement each other with the introduction of new technology. The steady increase in the impact in the field of international architecture design has formed a kind, simple and natural urban residential style which focuses on the function and the living environment. Countries in northern Europe are in the forefront of the world in the residential design with low energy consumption and sustainable development; the reasons may be as follows: the first reason is reflected in the national legal policy. The Nordic countries launched a series of legally binding building codes; there are certain restrictions on the use of energy, not only for heating, but also including lighting, ventilation, *etc.*; the second reason is to embark on the angle of architecture information design, in support of the advanced computer aided design and energy saving technology, designers have conducted a lots of low energy simulation and experiment, and the concept of sustainable development has rooted in design thinking. Architectural design has been placed in a wider social and economic context, the construction has undertaken the task to provide a better life for the public. In this regard, Sweden promoted the sustainable pilot residential quarters applied by the building information model, with the aim to demonstrate the practical effect of energy saving of urban residential area in cold regions under the guidance of sustainable planning and design and the integration of the mature building information model [6].

In Asian region, we take the neighboring country, Japan for example; more than 40% of the land is at high latitudes, in some important cities of cold regions such as Sendai and Sapporo, the residential construction uses a lot of prefabricated plate for field assembly in order to improve the residential humanization, intelligent and environmental design; water supply and drainage and gas pipeline have achieved the shortest path in the circuit arrangement through information model calculation, and the heat coverage area of heating equipment and the automatic control time of gas heating equipment has achieved the most economic level by means of the secondary development of software model simulation calculation. The rational distribution of pipelines in the building interior equipment effectively integrates space and creates more areas of use [7]. It is particularly worth mentioning is that Japan is in the active tectonic plate area, it has been a country with frequent geological disaster since ancient times, the residential seismic design is particularly important, the residential information model designed can conduct seismic force analysis and evacuation of detection through Solibri model checker (SMC) and other auxiliary software, greatly enhancing the urban residential practicability and safety in cold regions[8].The construction process of the urban residential building assembly in the cold regions in Sendai is shown in Figure.1.

Figure 1. Construction Process of the Urban Residential Building Assembly in the Cold Regions in Sendai

In September 2015, the author of the study was funded by the research project of studying abroad foundation, came to the University of Ottawa, Canada, and began a period of six months' study visit. During the visit, he has visited the main cities in Quebec, Montreal, Ottawa, Toronto, Calgary and Vancouver, gone to in-depth the residential construction sites, witnessed the application level of building information modeling technology in the residential construction field of developed countries in North America. The apartment-style residential in central cities has widely used reinforced concrete frame shear wall structure. The load design and thermal insulation energy consumption calculation of the building information modeling in the pre design process significantly enhanced the prefabricated level of building. First of all, at the level of building structure, the non-beam floor technology is widely used, which relies on the accurate calculation of the column to support the standard floor with hidden cap, reducing the amount of the concrete and significantly enhancing the clearance height of interior space as well; secondly, in the wall insulation design, the high precise precast shear wall integrates the processing of core layer, insulating layer and the surface layer, rapid on-site assembly can effectively shorten the cycle of construction, and directly reduce the environmental pollution caused by on-site concrete mixing and pouring ;At last, in the design of indoor wall and building curtain wall, the building information modeling is used for thermal insulation and sound insulation calculation, fully uses light steel keel support system; the environmentally sound insulating glass wool is filled inside, the OSB wood particleboard is dry hung in the wall surface layer. The design can effectively improve the recycling rate of building materials and reduce the weight of the structure as well. The construction site of Ottawa apartment residential is shown in Figure 2.

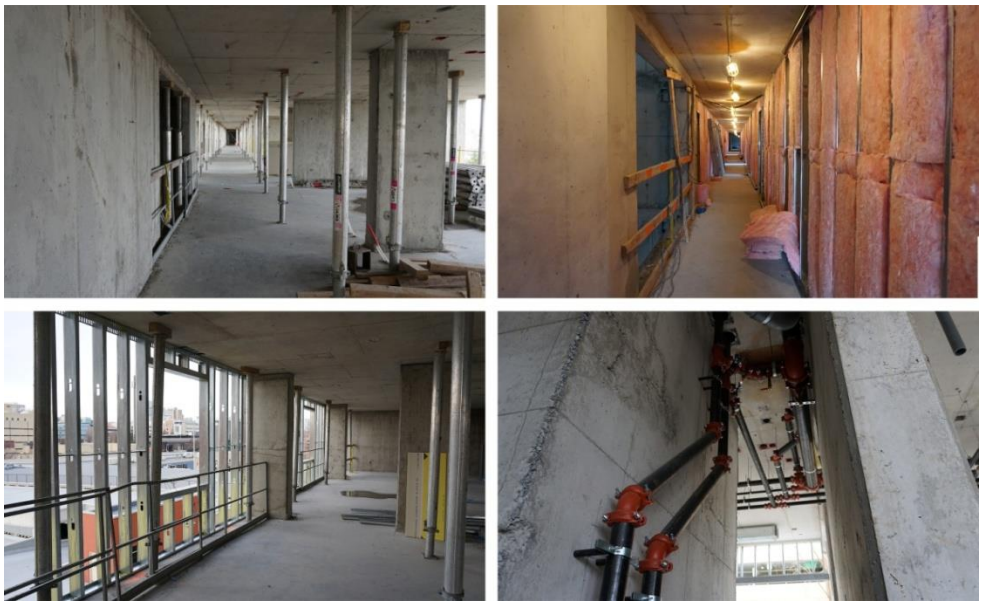

Figure 2. Internal and External Wall Technology of No Beam Floor and Light Steel Keel Structure Widely Used in Ottawa Apartment Residential

The application of building information modeling technology in the residential design in cold area has a late start, more support is given. During the twelfth five-year plan period, *"The Research and Demonstration on Key Technology of the Design and Construction of Residential Industrialization"* established the national scientific research project. The planning and design departments of various provinces and autonomous regions actively explore, and put forward the corresponding implementation strategy according to the local climate geological characteristics and the requirements of the specification. For example, Mr. Liu Weidong proposed sustainable building concept in the context of mass production of parameter design based on public rental housing industrialization production and construction methods, standard design of public rental housing and combination of components and construction in the construction practice "Beijing Public Rental Housing Demonstration Projects -- Zhong Mei Photosynthesis Original Project". Mr. Wan Chengxing proposed the method through the analysis and calculation of the structural data model to quick assemble integral type reinforced concrete main structure technology system in Shenyang Subway Lishui New Town Project, significantly enhancing the prefabricated parts level of engineering structure and the project quality of the project [9].

4. Application Process of Building Information Model

4.1. Instance Selection

The instance selected in the study is located in the Building No. 8 of real estate project in Dayu Brown Stone Park Residential Project of Changchun City High-tech Industrial District, its external architecture design and design of the housing type is the same with that of the concurrent engineering apartment Building No. 4; and the construction area is 5838 square meters. The facade design adopts the British Tudor style, there is a lot of pilaster and mountain flower modeling, the thermal insulation layer is made of 10 cm thick benzene plates, and the surface uses clay blot decorative surface. The building height is 24.3 meters with a total of 7 floors, and 28 units. The Building No. 4 has completed the construction process, which provides a good standard reference for the design of energy saving Building No. 8.The concrete dosage of Building No. 4 construction is 2650 m³, the length of PPR Water supply pipe with the size of DN25 is 112 meters, the length of PPR water supply

branch pipe with the size of DN15 is 355 meters, the length of PVC hoses with the size of DN110 is 134 meters, the length of steel gas pipe with the size of DN32 is125 kg, the exterior wall thermal insulation benzene plate is 2.557 tons, and the construction period is 16 weeks.

4.2. Application of Building Information Model in the Planning Stage

At the beginning of Building No. 8 residential planning and design, the establishment of building information dimension model exported data files by means of auxiliary test software: SMC, SUN2014, OVen2014, DALI2014, Navisworks, *etc.* to conduct the preliminary building rationality and energy consumption analyses, including wind environment analysis, visibility analysis, building sunlight analysis, solar radiation analysis and so on. The analysis results effectively helped construction and the design units adjusted the layout of the building's shape, realized a more comfortable natural ventilation environment and indoor lighting effect, further improved the urban residential green building comprehensive performance index in cold regions. The analysis results of sun light and shadow in the building information model is shown in Figure 3.

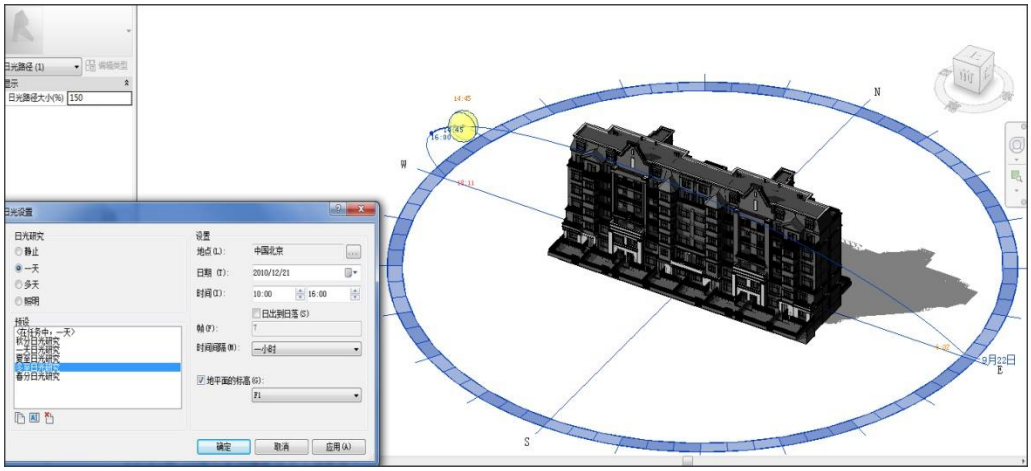

Figure 3. Sunshine Analysis Simulation in the Building Information Model

4.3. Design Adjustment of House Type Plane

The mission of the residential is to provide a more suitable indoor space for the house owners. Therefore, the special research on the characteristics of the living needs and living characteristics of potential housing residents has established a reasonable basis for the design of residential house type in the cold regions, and provided guidance data for the design units. The average construction area of the apartment layout in Building 8 is 125 square meters; the apartment layout pattern is three bedrooms with a living room hall and a bathroom. Most of the house buyers are the generation after 80s with 3 family members, they generally choose the apartment for the improvement of residential, and the use of three rooms is mainly the master bedroom, guest bedroom and child's room. The growth of the children need more and more storage space. And the degradation of the function of the television made the role of traditional public space in the family - the living room is increasingly weakened. The use of building information modeling technology slightly adjusts the apartment pattern and structural position, under the premise of guaranteeing the specified load, the thickness of the building shear wall and indoor masonry wall is reduced, re-adjusted the standard width size of the living room and child's room, effectively increasing the indoor usable area by 4.6%.The sun simulation and temperature calculation function of information model increases the glazing floor area ratio to 1/5.9, bringing a better lighting effect and landscape view for the interior space.

4.4. Optimum Design of Residential Facade

The facade design in this study adopts the Tudor England style, with huge flowers shape and A nice hour-glass wall column and inner concave open balconies. The decoration modeling of building facade is rich, which is realized in the dry hanging benzene plate spraying lacquer. The shape coefficient of the original construction plan is 0.32.Theoptimization design of the building information model precisely controls the convex depth dimension of the exterior façade shape. On the premise of ensuring the roof and balcony design catchment, the height of parapet is reduced. Finally, the shape coefficient is reduced to 0.305. As for the urban residential design in cold regions, the decline of 0.15 of the shape coefficient will effectively enhance the energy saving efficiency of the building. The final appearance design of the buildings.

Figure 4. The Optimized Appearance Design of Building No. 8 of Dayu Brown Stone Park Residential Project

4.5. Comprehensive Collision Detection

The multi professional collaborative design of building, structure, plumbing and electric will load the complete building information model into Navisworks for comprehensive collision detection. 12 designers are detected in the building external wall decoration and roofing water proof node; 2 design errors are detected in staircase beam wall phenomenon;10 design errors are detected in pipe wear beam, 20 design errors are detected in electrical switch and Bridge exposure; 16design errors are detected in the trunk pipe and branch pipe interspersion of the pipe, 8 design errors are detected in sewer pipes and toilet ware transfer bias. 12 design errors are detected in indoor water-supply pipe and the heating loop vertical tube interpenetration. The re-optimization of the design effectively avoided the collision of these circles in the early stage of construction, saved the costs of construction, shortened the construction period of the site design change. The equipment pipeline information model and collision detection results in the building are shown in Figure 5 and Figure 6.

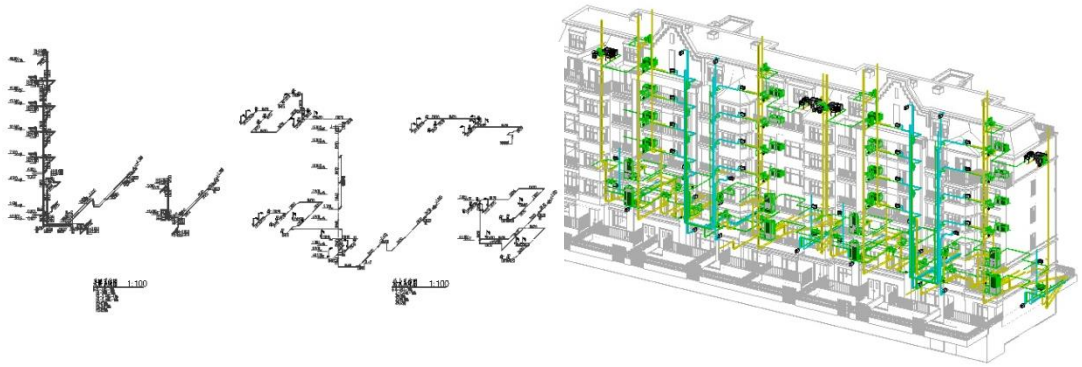

Figure 5. Equipment Pipeline System Diagram and the Building Information Model Contrast

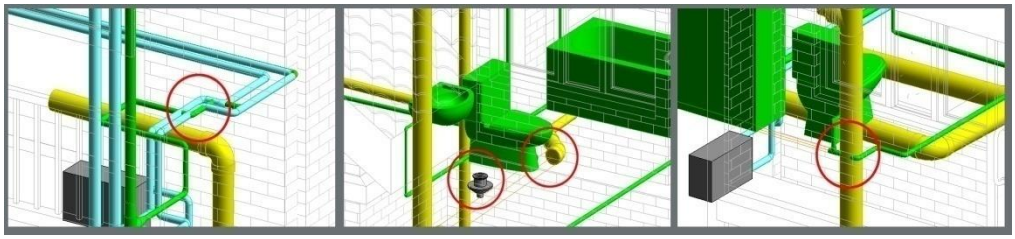

Figure 6. Typical Pipeline Ring Collision Node Signal

4.6. Engineering Building Materials Quantitative Statistics Helps Cost Control

The optimization design of the building information model will effectively classify, save the related project information, make the project data into an organic whole, help the construction units export the required information statements through model at any time in future, such as: the statistical tables of doors and windows, the statistical tables of number of components, the volume statistics of various types of precast concrete, the component category statistics and so on. The collation of relevant data can help the construction unit fast and efficiently compare the main economic indicators in the projects, and the model data will update with the progress of the project timely, so as to ensure the accuracy of project information [10].Refer to the completed Building No. 4, the amount of concrete of the Building No.8 in Dayu Brown Stone Park Residential Project after the optimization design of building information model is 2579 m³, the savings ratio is 2.678%; the PPR water supply riser with the size of DN25 is 101 meters, the PPR water supply pipe with the dimensions of DN15 is 338 meters, the PVC pipe with the size of DN110 is 130 meters, the overall savings ratio is 5.324%;the steel gas pipe with the size ofDN32 is 118 kg, the saving ratio is 5.6%; outer wall insulation benzene board is 2.482 tons with the saving ratio of 2.93%; and the construction period is shortened to 15 weeks. It is calculated that the direct and indirect cost savings is 4.3%, effectively reducing the waste of construction materials and environmental pollution.

5. Industrialization Prospect of Urban Residential in Cold Regions

At present, with the end of the first phase of urbanization construction, China's real estate market has entered the second phase of the fine, sustainable design; design units and construction units are facing more severe competition. The green energy-saving design requirements for the urban residential in cold regions put forward more stringent standards of

the pre design, based on the industry background, we see the inevitability of combination between the building engineering and building information modeling technology.

Although the vast majority of domestic design units adopt the two-dimensional engineering drawing in the design of building structure, many design units have popularized the application of building information modeling technology; some applications even cross the category of pre planning and design.3D visualization, multi professional collaboration, simulation and optimization and other powerful features fully meet the demanding needs of complex buildings, especially the collision detection, pipeline comprehension and other aspects have an immediate effect. The internal structure information of building structure reinforcement and maintenance system can be expressed with real details in the drawings, and be visually presented in the flat profile. It can be connected with structural design software interface, accurately define bar size and consumption volume; in component prefabrication process, the walls between the floors are connected mainly by outside the reinforced and connecting sleeve, model as a reference can more intuitive understand different floors wallboard connection method, to improve the production accuracy of the workers, and directly influence the construction efficiency; Building information model is applied in the construction process for deepening the design of complex components, reducing the rate of error, leakage, collision, greatly improving the design quality and efficiency. Based on the above reasons, the application example of residential design in cold regions of this study is only a cut of the popularization application of building information model technology; with the development of technology and the industry policy guidance, the industrialization of the urban residential design in cold regions and large-scale precast must become the mainstream trend, it is an inevitable choice to enhance the level of construction efficiency and reduce the pollution of the environment, and the early platform to achieve it is undoubtedly the building information model technology. In the positive outlook for the future, we still have to be aware of the challenges, which is the direction and power we continue to study in depth, the specific challenges are as follows:

a) Management risk

The urban residential design and construction prefabrication in cold region involves many professional engineering teams, including PC component hoisting, installation of water and electricity, cast-in-place, rough decoration *etc.* operations teams, and there exist certain crosses between them, and more difficult coordination easily influence smooth implementation of the project.

b) Technology risk

The prefabricated assembly support system adopted in this project implant the green building concept in the design, construction process, innovation, which bring smore and more technical difficulties. The collision and conflict of different professional teams is unpredictable, resulting in higher risk factors in project implementation.

c) Schedule risk

With the deepening of the design and the improvement of the precast rate, the number and types of PC components required is quite more. Due to the limitation of site yard condition, PC component cannot be piled up too much at one time. Therefore, the requirements of hoisting plan and transport type and quantity planning of the connection degree are very high, which has a great challenge on the schedule.

d) Quality risk

The building information model technology applied in the urban residential project in cold regions adopts the very strong innovative structure system and the construction technology, the previous construction experience and technology cannot be directly used into the project, increasing the risk of quality control.

e) Total responsibility risk

Site PC components usually have large quality and need enough lifting height., which is of a high security for lifting job, and after the PC components hoisting, before node pouring, it is

also needed to calculate stability of the temporary support, so the safety risk coefficient of installation process of residential components is very high [11].

6. Conclusions

The study is based on Building No. 8 residential case of the Dayu Brown Stone Park Residential Project in Changchun City, actively applies building information technology, fully participate in 3D data model from the pre-planning, building facade design, collision detection optimization until the construction cost control, which provides a new research reference for the urban residential in cold regions under the background of digital era. Accurate establishment of the model and data and simulation analysis enhance the depth and quality of design; avoid the defects in design and the waste of construction materials and environment pollution, which is in line with the construction philosophy of energy-saving environmental protection and rural environment and sustainable development of green building strategies advocated by the state The advanced technology and energy-saving emission reduction requirements also drive the urban residential industrialization design and construction in cold regions, and are bound to become an important means to improve the industrial structure, promote the sustainable development of the energy and resources in the northeast industrial base. The data file records in the whole process of the case study accumulated complete original data and valuable planning design, test simulation and cost control experience for the application and promotion of the building information modeling technology in future other projects of domestic similar latitudes.

Acknowledgements

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Author

Rui Han, College of Art, Jilin Jianzhu University, Changchun 130118, China