

Exploring the Protection of Ancient Buildings Based on BIM Technology—Taking the Han Family Compound in Shangli Ancient Town, Sichuan Province as an Example [†]

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Abstracts: As a digital innovation tool in the field of architecture and engineering, BIM technology can improve the efficiency and quality of projects, and also realize all-round information sharing and collaboration throughout the project life cycle. Most of the ancient buildings in China are wooden structures, which often face problems such as damage, corrosion, and insect infestation, but because of their high cultural value, the maintenance of ancient buildings is always subject to shackles. The effective combination of BIM technology and ancient buildings is conducive to all-round, detailed and in-depth maintenance and protection of ancient buildings. The Han family compound is located in Shangli Ancient Town, Sichuan Province, which is a well-preserved Qing Dynasty architectural complex in the ancient town. However, a fire in the Republic of China period, the earthquake in 2008, and tourism development in recent years, under the dual role of nature and man-made, the ancient buildings have been damaged and collapsed, and tend to assimilate with modern buildings, facing the dilemma of maintenance and protection. Therefore, this paper is dedicated to exploring the feasibility of combining BIM technology with the maintenance and protection of the Han Family Courtyard, and summarizing the specific application of BIM technology in the repair and protection of the Han Family Courtyard through domestic and international cases, so that the Han Family Courtyard can be developed in a sustainable way.

Keywords: architectural heritage; han family compound; ancient building maintenance; sustainable development

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1. Introductory

Western Sichuan Han family compound is relatively well-preserved and has a typical local style of the Qing dynasty courtyard houses. It is located in Shangli Ancient Town, Ya'an City, Sichuan Province, which is situated at the junction of four counties, namely, Mingshan, Qionglai, Lushan, and Yucheng District, and is a mountainous town with more distinctive characteristics among the historical and cultural cities in Sichuan [1]. Shangli, an ancient town of Han family compound, was built in the Qing dynasty Kangxi thirty-two years (1693), more than 300 years ago, four years before the Daoguang four quadrangle of ancient architectural complexes, preserved to this day, very architectural historiography and aesthetic and artistic value. Repairing and protecting old buildings have become the most common and solved problems of the Han family compound. How to repair and reinforce damaged ancient buildings through reasonable technical means to extend their life is a critical link in the repair of old buildings.

BIM technology provides indispensable technical support for protecting and restoring ancient buildings and reconstructing old building models due to its visualization, coordination, simulation, optimization, and charting advantages. BIM technology can share

the repair process through data on the Internet platform, significantly promoting the communication and development of the ancient building repair project. Therefore, it is significant to use BIM technology as a data platform to explore the feasibility of its broader application in old building repair projects.

2. Overview of the Han Family Compound

The whole building complex of the Han Family Compound adopts a pierced-dipper wooden structure. The top surface of the building complex is paved with green tiles, stone piers are used as column bases close to the ground surface, and the ground is paved with green stone slabs. Architectural craftsmanship is exquisite, the entire building of stone footing vent, column base modeling, and inlaid wood carving patterns beautifully modeled, rich in content, fully demonstrating the artistic talent of the ancients, expressing the concept of unity between man and nature and the pursuit of wealth and harmony of the goodwill.

The Han family compound was listed as a municipal cultural relics protection unit in 1985 and a provincial cultural relics protection unit in 2007. During the Republic of China period, the compound was destroyed by fire in the first courtyard. The government adhered to repairing the old as the old to restore the damaged appearance of the compound, but the repair work was stopped due to a lack of funds and many other problems [2]. After 2005, the government began to focus on building the Shangli Ancient Town's tourism program. The government received the right to use the third block of the compound for the museum's opening, but later, the museum was closed due to the operation of the funds and personnel management problems. After that, the property rights of the compound were jointly held by the government and the residents of the combination, which also resulted in an ambiguous situation regarding the management rights and responsibilities of the Han Family Compound.

With the development of the times, the buildings in the compound have a certain degree of aging; due to the local cultural relics regulations requiring the use of the same or similar materials for repairs, coupled with the 2008 earthquake led to the collapse of the ancient buildings have been damaged, the urgent need for a large amount of funds for repairs. In addition, tourism development has affected the compound residents' unauthorized additions and renovations, resulting in the traditional style of the Han family compound and other issues. Visible, for the Han family compound, later protection and repair work is significant.

3. The Application of BIM Technology in the Repair and Protection of Ancient Buildings

3.1. Application of BIM Technology in the Maintenance and Protection of Ancient Buildings at Home and Abroad

Using BIM technology, Wang Jingmin et al. investigated the possibility of extending ancient buildings' DNA gene protection technology to repair old buildings. They discussed the repair and protection of Lingyin Temple in Hangzhou [3]; Shi Ruoli et al. combined BIM technology with three-dimensional scanning technology and GIS technology to study the subject of ancient building repair and protection [4]; Zhang Ping et al. used BIM technology to reconstruct the model of the old Hakka buildings [5]. Petro Hryhorovskiy et al. studied the structural stability assessment and emergency repair method of large buildings based on BIM technology by taking a Ukrainian building as an example [6]; Carlo Biagini et al. studied the application of BIM technology combined with point cloud in the process of renovation and restoration of historical architectural heritage by taking the church of Nom De Maria as an example [7]; Americans Woo. Wilsman et al. combined BIM with various data acquisition tools in the building renovation project to reverse model the completed building and form a three-dimensional visualization model, which is convenient for the owner to formulate the renovation plan [8].

In summary, for repairing and protecting ancient buildings, scholars at home and abroad have established the information model of old building components through BIM technology; the virtual display of BIM is set based on three-dimensional scanning [9]. The main research direction is to restore the original appearance of ancient buildings, which is used to assist in repairing and later operating old buildings.

3.2. Advantages of BIM Technology in the Application of Ancient Building Repair

BIM technology information expression is very accurate, can realize a higher degree of ancient building repair information visualization, not only can restore the original appearance of the old buildings with high precision but also can visualize the historical and cultural information embodied in the ancient buildings, in line with China's antique building repair and drink protection of the original intention [10]. BIM technology is very flexible. The use of BIM technology to build the model can allow the design management personnel to review, supervise, use a three-dimensional perspective, look for errors, conflicts, and omissions in the repair, and timely put forward and correct the problem. Researchers can also use BIM technology to establish an adequate information base. Researchers can upload BIM data to the Internet and data sharing so that BIM technology can not only help in the process of ancient building repair information management for the later maintenance of ancient buildings to provide robust data support but also promote the development of the field of ancient building repair.

4. The Application of BIM Technology in the Restoration and Protection of the Han Family Compound

4.1. Collecting Data Information

Carrying out maintenance and preservation work on the Han family compound, the first step is to use BIM technology to carry out field measurements and surveys of the combination based on the principles of repair of cultural relics and buildings in Sichuan Province, local regulations, historical documents, current situation photographs, on-site surveys of damages, measured data for information, collection of spatial information of the ancient buildings of the compound, attribute information, and other data. Through the site survey damage, measured data to understand that the Han family compound is mainly three courtyards, with a building area of about 4600 square meters. The most urgent repair is currently the courtyard's third courtyard (Figure 1). The data from the initial measurements were organized to create an axis network and elevations in Revit and then to determine the location of the interior walls of the exterior walls and the slope of the sloped roof. The mansion is a courtyard, and the main room of the mansion has a face of five rooms, with a depth of seven purlins of about 12.5m; the left and right ear rooms have a front of three rooms, with a depth of five purlins of about 8.6m; the main hall has a face of seven rooms, with a depth of five purlins of about 7.1m; attention is paid to the creation of roofing details when constructing the model, and the floor plan of the first courtyard is finally drawn (Figure 2).



Figure 1. Collapsed portion of compound No. 1 of the Han Family Compound.

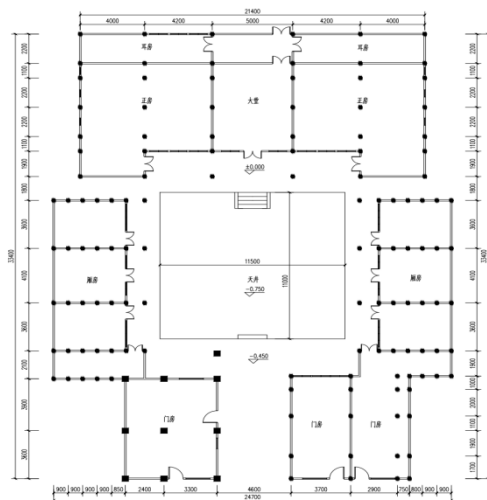


Figure 2. Plan of the one-entry courtyard of the No. 3 courtyard of the Han family compound.

4.2. Modeling

Based on the collected spatial information of the ancient compound architecture, Revit is selected as the modeling software of BIM technology. In Revit software, the “family” model is used to complete the establishment of the informatization model for restoring the Han family compound. The main structure of the compound’s internal ancient architecture is categorized according to purlins, eaves, rafters, beams, columns, and other components. The primary component size data are entered as parameters. For example, the columns’ diameter under the main house’s eaves is 260 mm, and the woods used are ginkgo, nanmu, redbud, red cedar, and sandalwood. The parameters are categorized into similar components, such as the columns’ diameter under the main room’s eaves, which is 260mm. Parameters will be organized into equal parts and parameter information. Repeat the above operation to form a database of ancient buildings in the Han family compound and gradually use the parameter information to build a preliminary three-dimensional model.

4.3. Information Entry and Association

In repairing the ancient buildings in the compound, while considering the restoration of the original appearance of the ancient buildings, it should also consider their humanistic value information and information on the surrounding environment. Among them, the attribute information includes the data collected on the building materials, primary structure, and external dimensions of the ancient buildings; the spatial information includes the photos of the ancient buildings that have been recorded and the various drawings and audio-visual data of the surrounding environment.

Because the compound ancient architecture has a lot of exquisite detail design, the BIM model construction needs to be fine structure creation:

(1) Doors and windows. First, select the “metric door” “metric window” sample file to create a new family, edit the family type data, improve the labeling information size, and establish a preliminary family model. Secondly, by observing the floor plan of the doors and windows, as well as spatial characteristics of the doors and windows, create a “stretch” model, and then create a “stretch” model. “Stretch” command, simple geometric shapes can be drawn through the “auxiliary lines” in the drawing panel, and complex lines can be completed through the “pickup lines”; then modify and check the thickness data of the doors and windows and check and perfect the doors and windows. Then, change and check the thickness data of the doors and windows, check and perfect the

overall effect of the doors and windows to complete the establishment of the family of doors and windows.

(2) Column. Create a family of metric conventional models, set the work surface as “elevation: front”, take the bottom of the column as the coordinate origin, use the “rotate” command to draw its boundary lines and axes, determine the direction of the baseline, enter the radius of the bottom circle of the column foundation stone and the height, determine the direction of the baseline again and enter the radius of the bottom loop of the column body, and determine the direction of the baseline. Furthermore, enter the radius of the base circle of the column body and height, forming a closed line to the vertical reference plane for the axis. After completion, click on the 3D view to generate the 3D model of the column.

It is worth noting that the courtyard of the doors and windows stone columns are all skillful carving, openwork, relief, and inlaid carving. The theme style is mostly auspicious beasts, birds, flowers, and patterns; traditional Chinese cultural stories include the Peach Garden, the Eight Immortals across the sea, and the Three Heroes battle Lv Bu. (Figures 3 and 4).



Figure 3. Carvings on the doors and windows of the Han Family Compound.



Figure 4. Carvings on the stone pillars of the Han Family Compound.

4.4. Establishment of an Information Base

A set of spatial and attribute information about the Han Family Compound is stored through BIM technology’s information entry and correlation. The report of each component in the information base should contain specific specifications, detailed dimensions, service life, replacement time, and maintenance precautions. The construction of such an information base facilitates the maintenance of ancient buildings after the completion of the restoration work. Maintenance personnel can follow the information base of the components of using life and replacement time nodes for maintenance. In contrast, maintenance records are stored in the BIM system data database cycle for the later maintenance

work to provide data support to achieve the purpose of the sustainable development of the compound of ancient buildings.

4.5. Building Modeling

First of all, use the façade of the compound ancient building to create the building elevation, select the plane to establish the corresponding axis network, load the column family and then use the “Architecture—Columns” to place the columns in the corresponding position and create the wall, and at the same time, give the timber texture; and then use the “Architecture—Roof” command to draw the shape of the roof, and set the length of the outstretched and the slope and other data, so as to form the overall effect of the compound ancient building; after the completion of the general architectural layout, set up the other architectural components, and improve the layout of the building through the loading of the independently created doors, windows and other building families, and finally through the three-dimensional view, the optimization of the overall situation of the ancient building and the details of the old buildings, the completion of the compound old building model modeling.

4.6. Simulation of Reinforcement Measures

Utilizing the virtual display function of the BIM system, the demolition and replacement process of the damaged part of the ancient building of the compound is deduced in advance, avoiding the risk of collapse and damage arising from the hasty demolition of components while protecting the ancient building, the safety of the construction process is increased and controllable. Through the reasonable use of the BIM visualization projection function, in advance of the repair process to expose the components of the demolition and replacement work, safety measures and reinforcement measures set up on the ancient architecture of the risk of damage to the repair program for the optimal selection to assist.

5. Conclusions

This paper applies BIM technology to establish the repair project database of the ancient buildings of the Han Family Compound, which provides a series of practical and intuitive repair and protection technical support for the managers of the old buildings of the Han Family Compound, such as design correction, construction program evaluation, reduction of project cost, process quality supervision, avoidance of secondary damages, and construction safety management. It can also show the historical style of the ancient buildings for the tourists through the panoramic display function. Based on BIM technology, it should also be combined with the protection strategies of IPOGEA and ITKI to carry out the protection of the ancient buildings of the Han Family Compound: start from the region, improve the dire situation caused by natural disasters, comprehensively utilize the concept of all the historical resources of the Han Family Compound and integrate with the nature, so that the entire Han Family Compound is integrated into the ecology of this “big museum”. The technical study of the renovated part of the Han Family Compound will utilize local environmentally friendly and renewable materials to design an environmentally friendly building with low energy consumption and CO₂ emissions, thus realizing the sustainable development of the compound.

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