

Protection and Development of Traditional Stone Residential Villages Based on BIM Technology: A Case Study of Dakou Village

Yan Mao^{1,a}, Jianlan Xiao^{1,b}, Xiaofang Bi^{1,c,*}

¹College of Architecture and Art Design, Henan Polytechnic University, Jiaozuo, China

^a312003861@qq.com, ^b1989179036@qq.com, ^cbixiaofang@hpu.edu.cn

*Corresponding author

Abstract: BIM technology provides a three-dimensional and visual means for the construction industry, which has certain advantages in traditional building protection. As a kind of historical material heritage, traditional Chinese houses have their own humanistic values. In this paper, a stone-built house in Dakou Village on the Taihang Ancient Road is taken as an example, through surveying and mapping, the traditional house is established by using REVIT software, and a complete architectural model is formed through the insertion of the "family", and the plan, axis and perspective view of the building are obtained, which shows the application and advantages of BIM technology in the visualization of traditional houses, and proposes the protection and development of stone houses.

Keywords: BIM, stone dwellings, conservation and development

1. Introduction

As a form of traditional dwelling, traditional stone houses are particularly prominent in mountain and forest areas. Under the influence of natural conditions and humanistic culture, different types of stone houses have been built in different regions, and in terms of architectural form, there are flat-roofed types in Tibetan areas and gables in the Central Plains as representatives. The Dakou village dwellings located along the Taihang River use yellow sandstone and green sandstone as the main building materials, bricks as auxiliary materials, lime as the bonding materials, and wood as the beams and slabs of the building, forming a two-story structure of stone houses, showing the distinctive construction characteristics of the Taihang Mountains.

Since BIM technology was proposed in 1970, it has gradually been industrialized, standardized and standardized^[1]. In the application of traditional architecture, BIM technology omits architectural design, and shifts the focus to four aspects: traditional building basic information collection, building "family" 3D model construction, building overall model construction and building life cycle management. Visualization is one of the characteristics of BIM technology. Help with architectural design related to the planning process party is better to understand and communicate information about construction projects. Convert building models into 3D models or virtual reality models, Gain a more intuitive understanding of the exterior of a building project, the layout of the space, the choice of materials, and the structural details. In the construction of traditional timber projects, by establishing purlins, fangs, columns, dougong and other modeling, to build a three-dimensional model to achieve the optimization of the project plan, the construction of the project drawing objectives, so that the problems that may arise in the construction of the building are revealed^[2-3].

2. Overview of Dakou Village and its dwellings

2.1 Overview of Dakou Village

Dakou Village was called "Hengwang Pass" and "Hengwang Town" in ancient times, located in the south of Zezhou County, Jincheng City, south of Taihang Mountain in Shanxi and Henan Provinces, and belonged to Jinmiaopu Town, Zezhou County, and the village is located at the junction of Taihang, Shanxi and Henan Provinces on the ancient road. Since ancient times, Dakou Village has been used as an important pass and passage of the ancient road, and has the reputation of "the first village in Taihang in

the north". The mountains in the region are vertical and horizontal, the terrain is dangerous, it is the main pass of Taihang Mountain, so it is called "Dakou".

Dakou Village sits in the north and faces south, and is scattered by the mountains, with the highest altitude of 906 meters. At the heights, you can look at a radius of 100 miles, and the surrounding Jincheng City, Henan Jiaozuo City, Boai County, and Qinyang City are in full view. The Great Wall of the Northern Qi Dynasty and Mengliang Village in the north of the village are provincial key cultural relics protection units; The ancient sheep intestine board road passes through the village, and it is the only place for the tea ceremony of China and Russia; The artillery tower built by the invading Japanese army in the thirties on the mountain north of the village truly records the crimes of the Japanese invasion. In 1938 and 1939, the Nationalist Army heroically blocked the Japanese army from moving north for 49 days, and the villagers sent ammunition and food, composing an ode to patriotism. The ancient road has been around for 3,000 years, and the first line has traveled to the south of Taihang. The rich historical culture and precious historical sites of Dakou Village make this ancient village on Taihang Mountain full of infinite charm.

2.2 Overview of Dakou Village

The walls of the traditional houses in Dakou Village are mainly masonry mixed walls and stone walls, with wooden floor slabs and roof beams, which are built into gabled buildings. In the masonry, different stone types and sizes are selected to show a peculiar architectural appearance, the roof faces the south, and a few are built along the ancient road on the east and west sides. Most of the dwellings in the village are well preserved, mainly with hard mountain tops, stone walls, grid windows, and swing doors, and according to different uses, they used to be used as inns, shops, and ordinary houses. Most of the buildings are built into two-storey buildings, and the two-story houses are entered through an outdoor stone staircase, and a few are one-story structures, and there are few partitions in the building rooms due to different architectural forms. At present, most of the dwellings in the village are uninhabited, and many dwellings have the phenomenon of tilting and collapsing of building walls, in order to record the original structural form of the dwellings, the BIM technology is used to digitally store the building structure, show the architectural appearance and structural form, and preserve the traditional construction skills. This is shown in Figure 1 and 2 below.

According to the principle of "tripartite rule" of architectural aesthetics, the dwelling is divided into three parts: the stone base, the main body of the building and the roof from bottom to top^[4]. The stone base is composed of relatively regular bluestone, with a height of about 300mm. The front and rear walls of the inverted seat house are made of bricks, the gable is made of bluestone and yellowstone masonry, and the rest of the main body of the building is a stone masonry wall, which is mixed with bluestone and yellowstone to show an irregular architectural appearance, and the thickness is between 100mm-300mm, the length is about 500mm, and the width is about 400mm stone for masonry. The roof is paved with green tiles to form a dry tile, and the roof frame is a mixed frame, with a wooden floor on the first floor. The doors, windows and lintels are made of wood.



Figure 1: Courtyard (Image source: self-photo)



Figure 2: Courtyard (Image source: self-photo)

2.3 Existing problems of residential buildings

With the development of the times, new changes will inevitably occur, and while people pursue good living conditions, traditional buildings can gradually fail to meet the living requirements of residents, and then lose the natural features of traditional buildings. The main manifestations are: 1. The new buildings are more modern, which is arranged and combined with the traditional houses to form a village, which loses the original sense of natural harmony, highlighting the chaos of the overall village style. In the new building, the residents use red brick masonry walls, the roof adopts the traditional style of gray roof, the wall is red or painted into a white wall, the colors are mixed with each other, the contrast is obvious, compared with the original color of the traditional stone house, the building façade wall stone is conspicuous, giving people a rough and natural feeling. Second, young people began to go out to beg for a living, began to settle down in the big city, in addition to the courtyard where the elderly lived, there are many houses collapsed, with the aging aggravation, the houses gradually become uninhabited, which makes the phenomenon of idle houses further aggravated, and the collapse of residential buildings is inevitable.

3. Based on BIM stone courtyard shape protection

3.1 "Family" model construction

As an important part of the building model, the "family" uses the typology method to classify and model the building components, so as to reduce the modeling workload in the later construction of the overall model. Revit has a powerful parametric element and parametric modification engine in the 3D parametric architectural design software for the construction industry, and each type can have different dimensions, shapes, material sets or other parametric variables according to the needs of the model. The family editing platform provides a relatively complete modeling method, parameter type, and parameter assignment method, and can transmit the corresponding parameter values through the use of nested families, which makes it possible to establish basic parametric components of ancient buildings, and to model the overall parametric modeling of ancient buildings based on them^[3]. Construct the door "family", establish the appearance of the model and mark the parameters, and show the structural form and size of the door and window. This is convenient for later modeling the building as a whole.

3.2 Door and window construction family preservation

1) Gate "Family"

After the basic building information collection is completed, the traditional building construction is classified to obtain the 3D model of the "family". The courtyard house shown in the picture above is selected, which has 11 doors and a hole on the façade. According to the door style, there are 5 types of doors on the first floor and 1 type on the second floor, all of which are swing doors. The door lintels are made of wood. In this building, the main difference between the doors is the door head frame, which is mainly divided into oblique wooden strip grid door head and wooden vertical strip grid door head. In the component family door model, the basic size of the door is set first, and after the basic new components of the model door are completed, the door buttress, door lintel, and door head window are added, and the component position is locked, which is convenient for the later "family" insertion, and finally the material is modified. In the form of a two-story door, due to the influence of the height of the building, the door is not equipped with a door head, and is also equipped with a door buttress, a door frame and a wooden door lintel.

2) Window "family".

According to the window style, the windows are divided into four types, of which three styles of windows are directly in front of the inverted house, and the other style is the other 24 window styles. The window lintels are wooden structures, and the bottom of the windows is set with slat-shaped bluestone. All of them are grid windows, and the thickness of the wooden strips is about 10mm. The window "family" is built the same as the door "family".

3.3 Structural information of stone courtyard houses

1) One-story floor structure

The timber frame of the roof can be divided into five parts, from low to high, which are girders, secondary beams, wood strips, planks, and screeds. The girder is arranged on the stone masonry wall, and the depth of the wall is about half of the thickness of the wall, the secondary beam is located on the girder, and the spacing is about 400mm, and the wooden strip is set on the secondary beam, the spacing is about 300mm, and the wooden plank is built on the wooden beam at the same time, and then leveling is carried out. The building model is built in layers, with spacing set sequentially.

2) Roof beam frame structure

The two-story roof adopts the mixed frame of traditional houses, the height of the beam frame is about 2000mm, the stone house adopts the beam frame directly on the stone wall, and the bottom five beams are used as the main support part of the roof, and the five beams are deep into half of the thickness of the wall, and the overall building has no wooden columns, which is obviously different from the wooden frame form in other ancient buildings in China. Based on the typology, the family model was constructed as five beams, three beams, lower gold purlins, upper gold purlins, ridge purlins, melon columns, ridge melon columns, horn backs, and spine fangs. After that, the beam-frame relationship "family" model is carried out. Compared with the two-dimensional plane, the relationship between the beams of the stone dwelling, the purlins and columns, and the existence of other structures are carefully reflected in the model. This is shown in Figure 3 and 4 below.

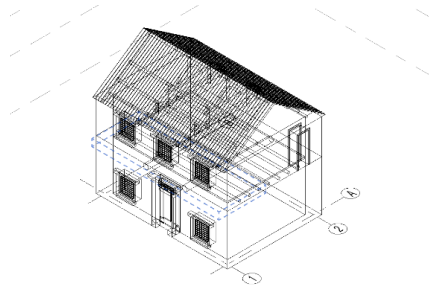


Figure 3: Perspective view of the wing room (Image source: self-drawn)

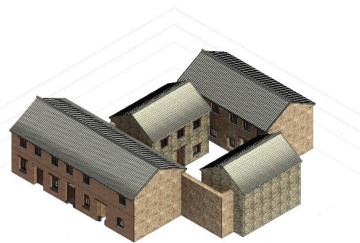


Figure 4: Model of the courtyard (Image source: self-drawn)

4. The protection process of stone dwellings based on BIM technology

Based on BIM, a three-dimensional model of the village dwelling can be established, and its history, cultural relics, materials and other information can be entered synchronously to achieve comprehensive recording, protection and management. In the process of conservation, BIM also provides visual data analysis tools that can help decision-makers better understand the environment, structure, and condition of the building to provide a scientific basis for the effective establishment of protection schemes. Through the in-depth investigation of the traditional stone houses in the village, the main functions, spatial layout and structural layout of the houses are understood, and the overall construction skills of the village are summarized, so as to provide a basis for the restoration of damaged historical houses. BIM technology is used to restore the historical stage, protect the current stage and maintain the traditional stone houses, establish a BIM project management process, and protect the digital stage of stone houses.

4.1 Historical stage restoration

In the historical stage, the basic dimensions of traditional stone houses are recorded through field research, interviews, and measurements, including roof tiles, dripping tiles, etc., the size of wall stones, eaves stones, pedestals, etc., the size of door and window lintels, door and window frames, etc., to record

the size and structural style of traditional residential structural components and have an in-depth understanding of their construction technology. The purpose of this is to solve the problem of preserving the shape and size of the existing dwellings. Surveying and mapping of residential buildings is the most important part of the preliminary work of residential protection, which requires a large number of surveying and mapping of residential buildings and summarizing the size and regularity of the shape. Residential surveying and mapping includes the steps of preliminary data collection, on-site surveying, mapping, verification and archiving, among which on-site surveying is the key to residential surveying and mapping. Through on-site measurements, we have a more comprehensive and intuitive understanding of the dwellings. After hundreds of years of development, in order to meet the requirements of residents for the living environment, the villagers have made certain modifications to the houses, such as replacing doors and windows, adding modern decorations, wall painting, etc., so that the existing appearance and the original appearance are combined and the overall sense is abrupt. At the same time, before the restoration of the original historical appearance of the residential buildings, the reverse architectural model of the residential buildings was constructed according to the oral accounts of the residents and the existing historical traces, and then the original appearance of the historical buildings was obtained through BIM.

4.2 Protection of the status quo stage

The protection of the current stage is based on the preliminary investigation and surveying, and the 3D model of the stone dwellings is numerically protected, the historical information is preserved, the structural performance is optimized, and the material strength is determined through BIM. In the current stage, there are two protection measures, one is to use BIM technology to digitally model the appearance and structure of existing houses, and show the building construction technology through three-dimensional models, combined with "family". The information records the status of existing dwellings, and obtains information on the current status of dwellings. The second is to use the existing model to simulate and optimize the building performance of building components, reflect the outstanding parts of the problem, and establish information visualization. The structure of rural dwellings is simple and crude, and the craftsmanship of building dwellings is rough. As the main structure of the building beam, the wood structure is composed of organic matter such as lignin and cellulose, which is easily affected by insects, dampness and decay, and structural instability. When solving such problems, the protection strategy is proposed at the beginning of the building construction, and after the family model is established, the construction method and construction points of the residential house are displayed with the three-dimensional model. Propose complete protection measures.

4.3 Late stage maintenance

Traditional dwellings are usually constructed of materials such as wood, adobe, and tiles, and require regular maintenance and restoration to keep their structures stable and functional. This includes repairing broken walls, roofs, floors, etc., and maintaining the details. Due to the invasion of nature and man-made damage, it is necessary to repair the houses to a certain extent. Stone dwellings are built into two-storey building structures, with stone walls bearing loads, although the stones have good physical properties, but the process is complex, so residents use different sizes of dwellings to build when building stone dwellings, coupled with the instability of the physical properties of the bonding materials, resulting in the internal problems of the stone masonry wall, so that the main problems of the dwellings have two points: 1. The instability of the stone wall. 2. Wood components are easy to corrode and burn. In the later stage of stone houses, in addition to meeting the requirements of structure and safety, it also shows the appearance and aesthetics of the house building and shows the original appearance of the building.

5. Conclusion and outlook

For the stone houses, the existing conditions of the courtyards of the houses are extracted, including the forms of doors and windows, and the village-level family library is established, the building components are extracted, and the construction process and building construction technology are carried out to show the complete modeling process. Later, according to the existing pattern of the dwellings, the historical appearance of the damaged dwellings was repaired, and the model was constructed to restore the historical form. Drawing on the styles of doors and windows of other buildings and the existing traces of the building, the establishment family is inserted into the building to restore the historical appearance, and then the overall appearance of the courtyard of the house is obtained. After the establishment of the

model of the residential courtyard, the post-management is carried out, including the building masonry style, the number of components statistics, the size information record, comparison, etc. At the same time, with the help of other engineering simulation software, the structural performance and physical environment of the residential buildings are analyzed, and the corresponding effects are applied to the residential buildings to improve the living conditions. Corresponding to the three stages of protection measures, the restoration of the historical stage, the protection of the current stage, and the maintenance of the later stage.

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