Research on Rural Community Construction with Modern Rammed Earth Materials

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Abstract. The soil exists in the vast countryside. Rammed earth materials are an important part of the growth process of rural dwellings. With the emergence of the homogenization of architectural style and the lack of cultural atmosphere of rural characteristics in the construction of beautiful countryside, the development and application of modern rammed earth materials will help the future construction of rural communities. Taking rammed earth dwelling houses in Sichuan as the research object, this paper constructs the livability evaluation system of rammed earth community, analyses the evaluation of residents' satisfaction, and thus obtains the optimization strategy of modern rammed earth dwelling houses. From the theoretical perspective of "Ternary mutualism", the relationship between modern rammed earth materials and rural communities is mutually beneficial, that is, modern rammed earth materials are the natural foundation, charm display window and practice platform of rural communities, and rural communities are the embodiment of the value of modern rammed earth materials, protection continuation and multiple innovation. Based on this, the construction path of modern rammed earth materials in rural communities is proposed, in order to provide reference for the construction of rural communities using modern rammed earth materials. The research results show that modern rammed earth material, as a unique construction material, is conducive to the construction of rural communities in harmony with the natural ecological environment of the local landscape, and plays a role in the protection and inheritance of local culture.

1. Introduction

Soil, as one of the most widely used materials in China's traditional buildings, has attracted increasing attention due to its outstanding ecological benefits, recycling, low cost, cool in winter and cool in summer, and so on. The building technology has undergone several advancements and developments from the primitive society to the Ming and Qing Dynasties. In the Ming and Qing Dynasties, there have been world cultural heritages—the “Tulou” in Fujian and the multi-storey rammed earth houses of Sichuan and other places [1]. The research and application of modern rammed earth materials abroad is earlier than China. Now China has achieved remarkable results with the use of modern rammed earth materials. The post-earthquake reconstruction project of Maanqiao Village in Liangshan, Sichuan Province and the new rammed earth residential project in Macha Village, Huining
County, Gansu Province, Gansu Qingyang Maosi Ecological Experimental Primary School, Hangzhou Fuyang Wencun Transformation Project, etc., were based on modern rammed earth materials and had built a rural residential area that was economically reasonable, practical and suitable for local residents. Therefore, after thousands of years of ramming soil, carrying forward the inheritance, as one of the source of our country's unique culture, there is still a great sense of existence and research value.

With the frequent homogenization of rural community construction and the lack of local characteristic culture, people pay more and more attention to the human settlement environment. The concept of community construction proposed to change from material function to comprehensive attention to the human settlement environment and continuous improvement of the community planning system \[2\] became the main point. At the same time, it integrates the five new development concepts of “innovation, coordination, green, openness and sharing” \[3\] to highlight the cultural characteristics of local characteristics. According to the data from the sample survey of the national rural housing status of the Ministry of Housing and Urban-Rural Development from 2010 to 2011\[4\], raw soil houses account for 16.4% of the total survey, and more than 40% raw soil houses in the western regions of Tibet, Yunnan, Gansu, Xinjiang, etc.

2. Materials and Methods

2.1. Overview of the study area

The research area is Jinjia Town of Shehong County, Suining City, Sichuan Province. It is located in the northwest of Shehong County, with longitude 105°E, latitude 30°N, 17km from the county, and the town covers an area of 48.72 sq. km. The land is a hilly landform with a maximum altitude of 535 meters and a minimum altitude of 334 meters. It is a subtropical humid climate in the Sichuan Basin, with abundant sunshine hours, abundant annual rainfall, four distinct seasons, and an average annual temperature of 17.20°C \[5\]. It has become a "pilot town for the construction of small towns in Sichuan Province “and "a beautiful environment town in Sichuan Province ".

In the town of Jinjia, there are still many rammed earth houses. According to field research, most of rammed earth houses are still inhabited by residents, and there is a low level of derelict housing. The overall structure remains relatively intact, but the cracking of the rammed earth wall is serious, in front of house debris piled up phenomenon is obvious.

2.2. Data Acquisition and Analysis

Taking Jinjia Town of Shehong County in Suining City as the main research area, field observation, questionnaire survey and interview methods were used to obtain data. A total of 160 questionnaires were obtained during the survey, including 151 valid questionnaires and 9 invalid ones, with an effective rate of 94.4%.

By constructing a livability evaluation system for the rammed earth community, the weight values of each indicator are determined to indicate the importance of different indicators. The questionnaire data was statistically analyzed, and the five-level satisfaction score was obtained. The current situation of the bauxite community in the research area was analyzed from five levels, and the community lacks and feasible points.

3. Results and Analysis

3.1. Construction of Rammed Earth Community Habitability Evaluation System

The evaluation index of the livability of the rammed earth community is different from the selection of the livability evaluation index of the general community in the construction materials of the community. However, as the main research object, the rammed earth houses are important in considering the relevant evaluation indicators that the rammed earth elements may affect the livability of the community. Therefore, starting from the principles of science, system, operability, dynamics, and typicality, after the literature analysis, expert review, and resident interviews, five first-level indicators and 28 second-level indicators were selected. On this basis, using the analytic hierarchy process, five anonymous peers were invited to score the importance of each index according to the 9-
point scale method, and the weight value of each indicator was determined by using the “yaahp V10.3” software (Table 1). It can be seen that the housing conditions of the primary indicator has the highest weight value, followed by infrastructure, ecological landscape, community cultural environment and social economy. The weight values of the secondary indicators are significantly different.

| Target layer element | Criterion layer element (Weights)                                      |
|----------------------|-----------------------------------------------------------------------|
|                      | social economy (0.1219)                                               |
|                      | cultural level (0.0166)                                               |
|                      | per capita income (0.0586)                                            |
|                      | household consumption level (0.0113)                                  |
|                      | ecological landscape (0.1802)                                         |
|                      | greening level (0.0451)                                               |
|                      | local landscape (0.0451)                                              |
|                      | sustainability (0.0901)                                               |
|                      | housing conditions (0.3389)                                           |
|                      | planning layout (0.0255)                                              |
|                      | living area (0.0077)                                                 |
|                      | structural safety (0.0991)                                            |
|                      | auxiliary housing (0.0091)                                            |
|                      | infrastructural (0.2356)                                             |
|                      | road facilities (0.1009)                                             |
|                      | water supply facilities (0.0601)                                      |
|                      | drainage facilities (0.0404)                                          |
|                      | power telecommunication (0.0194)                                      |
|                      | sanitation facilities (0.0148)                                        |
|                      | community cultural environment (0.1233)                              |
|                      | supporting service facilities (0.0117)                               |
|                      | public security conditions (0.006)                                   |
|                      | neighborhood relations (0.0415)                                       |
|                      | public space (0.0117)                                                |
|                      | cultural atmosphere (0.0123)                                         |
|                      | mental belonging (0.0171)                                            |
|                      | cultural heritage (0.0229)                                           |

3.2. Analysis of Resident Satisfaction Evaluation

Taking Jinjia Town, Shehong County, Suining City, Sichuan Province as a sample, in the questionnaire, questions were set on the indicators of the livability evaluation system of the bauxite community, and the rating level was formulated, including very satisfied, more satisfied, basically satisfied, less satisfied, and dissatisfied. From the 151 valid questionnaires, the residents' satisfaction with the community was counted (Figure 1).
At the socio-economic level, more than 50% of the residents are not satisfied with their income. This is also due to poor industrial development and cultural deficiencies, which have led to backward economic conditions and stagnant development. At the ecological landscape level, more than 70% of the residents are basically satisfied with the green landscape of the area, indicating that one of the advantages of the village is the beauty of the ecological environment. At the same time, residents support the sustainable landscape shaping and ecological protection. At the housing level, residents believe that the structural safety, seismic performance, ventilation and lighting of the earthenware house are poor, and more attention should be paid to building structure safety, material use, seismic performance and livestock breeding. For the use of rammed earth materials, about 40% of the residents do not support the continued use, and about 20% of the residents feel satisfied and support the use of rammed earth materials, and believe that there is still value. At the infrastructure level, residents have poor satisfaction with roads, water supply and drainage facilities. The construction of facilities has not yet reached the basic level of convenience and sanitation. Residents are basically satisfied with the construction of power telecommunications and sanitation facilities. At the level of community cultural environment, residents are very satisfied with the neighborhood relationship and public security status of the current place of residence, indicating that the overall living atmosphere of the place is good. Among them, residents' dissatisfaction with public space is higher than 50%. Many residents have put forward opinions on this, hoping to increase the space for public activities of concentrated residents and promote exchanges.

3.3. Analysis of Modern Rammed Earth Community Optimization

In view of the existing problems in the present-day rammed earth community, the following three aspects of optimization and improvement methods were obtained through literature review and classification.

Improvement of rammed earth materials. The traditional rammed earth dwelling use soil and straw materials. According to the evaluation results, the rammed earth material has poor durability, the soil moisture content of the earth wall is not scientifically controlled, the density and strength are poor and the waterproof performance of the material is weak. In response to these problems, Mu Jun, Zhou Tiegang and others conducted research and practice of modern rammed earth materials. Through laboratory tests and on-site construction practices, they found that the use undisturbed soil or the incorporation of 5% or so of hydrated lime from the waste soil of the wall and control of 15-20% of moisture [6] can greatly improve the mechanical properties and durability of rammed earth walls.

Optimization and improvement of ramming technology. Traditional ramming technology using wood formwork for manual rammer ramming has resulted in insufficient compactness, poor strength and inflexible operation of rammed earth walls. At the same time, residents are not willing to choose such construction methods because they are time-consuming and laborious. With the development of modernization, it is now possible to use new technologies and new equipment to increase the efficiency of traditional ramming processes and ensure high-quality construction. Some research teams have found out through on-site construction inspection that they can adopt modern flexible and sturdy stencils [7] with L or T-shaped stencils at the corners, and then remove the template, shovel the end of the wall into an inclined plane and correct the overall rammed earth wall [8].

Anti-seismic performance and structural optimization of the rammed earth houses. Due to the limited technical means and economic conditions at the time of construction and the lack of active and effective prevention and control measures, residents generally believed that the anti-earthquake performance of the rammed earth houses is poor and the structural safety needs to be improved. The foundations of rammed earth houses are often seriously damaged by corrosion and are not treated with water and moisture. The walls are simply built and shaped, and the concrete walls do not adopt effective structural measures, resulting in structural instability, cracking of the walls, and poor integrity. The roof is lapped directly on the rammed earth wall by the wooden strips, which results in cracking of the wall and in the event of an earthquake, which is likely to cause the collapse of the earthen houses. Based on the collected literature and books, a summary analysis of the improvement of the seismic performance and structural improvement of the rammed earth houses is carried out, as shown in Table 2.
Table 2. Summary table of improvement methods for structures in the rammed earth houses [9,10]

| N/S | Item               | Instructions                                                                 | Graphical Representation |
|-----|--------------------|-----------------------------------------------------------------------------|--------------------------|
| 1   | foundation         | set 300-500mm brick, stone or concrete foundation; set moisture barrier between foundation and rammed earth wall | ![Graphical Representation](image1) |
| 2   | wall structure     | set at the junction of the four corners of the rammed earth house and the inner and outer walls | ![Graphical Representation](image2) |
|     | wood structure     | set horizontally in the top of the rammed earth wall to enhance the integrity of the rammed earth house; connect the wooden ring beams by lap joints or picks | ![Graphical Representation](image3) |
|     | column             | long horizontally-pulled bamboo strips are arranged inside the rammed earth wall, and lashings are made at the junction between the vertical and horizontal walls | ![Graphical Representation](image4) |
|     | wood ring beam     | in the upper and lower seams of the rammed earth wall, set up vertical pins such as short wooden sticks and bamboo strips with a spacing of not more than 1 meter | ![Graphical Representation](image5) |
| 3   | building and roof structure | sandwich floor structure lamellar wooden beams are placed on the cross walls and gables, and they are seamlessly fixed to each other and connected with horizontal wooden beams | ![Graphical Representation](image6) |
|     |                     | roof purlin structure a wooden pallet is placed under the wooden purlins to reduce the local compressive stress of the wooden truss; set the wood wall to resist earthquake | ![Graphical Representation](image7) |
|     |                     | wooden slope roof structure the wooden rafters are under the wood purlin, and the wooden rafters are laid with bamboo mat, grass mud, and green tiles | ![Graphical Representation](image8) |

3.4. The relationship between modern rammed earth materials and beautiful-countryside characteristic cultural communities

The rammed earth, after thousands of years of existence, is an important component to accompany the growth of rural areas. Today, the development and application of modern rammed earth materials will also help the future development of rural areas. The community, starting from the house, gradually merged into culture, life, and the environment to make it a pleasant farmhouse. With the rapid development and homogenization of rural community construction, we have to initiate some reflections: Will the construction of a community that has abandoned rural elements lead the society to advance to modernization? Can the use of rural elements effectively promote the creation of distinctive culture and enhance the residents' life satisfaction? In terms of problem reflection, it is not difficult to find that the coupling relationship between all the elements can be analyzed around the three main factor elements. The three main factor elements are finally in the most stable state of the
triangle. This is the concept of "ternary mutualism" proposed in this paper. Among them, "ternary" is natural condition, humanistic factor, and technical means. Natural conditions include local natural resources, climate, hydrology, geographic location, living environment, etc. to reflect important basic information. The humanities elements mainly include customary personalities, cultural qualities, epochal factors, aesthetic concepts, etc. to reflect the value of human culture. Technical means mainly include the use of materials, construction capabilities, and technology levels to reflect the feasibility and innovation of the construction system. Natural conditions as a good foundation, coupled with the strong guarantee of technical means, eventually showed a brilliant trend in the humanities. Based on the actual investigations, research data analysis results and excellent demonstration projects, this paper explores the deep relationship between the following aspects of modern rammed earth materials and the construction of rural communities that reflect the beauty of rural unique culture from the perspective of "ternary mutualism".

"Ternary mutualism" - perspective of natural condition. Modern rammed earth materials are the natural foundation of the cultural community with special features. Soil, everywhere in the country, is rich in natural resources. Compared to icy concrete and brickwork, it is a warm harbor for residents. For the construction of characteristic cultural communities, the current emphasis is particularly on ecological construction and sustainable development. Modern soil-based materials are an excellent natural foundation. Taking this as a starting point, they can add a strong natural and ecological atmosphere to the construction of communities.

Characteristic cultural community reflects the value of modern rammed earth materials. At present, some residents still have old ideas. They believe that rammed earth materials are representative of poverty and that they should be eliminated on time. However, the emergence of modern rammed earth materials is now saving this primitive ecological feature. After the completion of the construction of a unique cultural community based on modern rammed earth materials, due to its economical and convenient construction methods, different visual and tactile experiences and the unique advantages of being warm in winter and cool in summer, it has changed the residents' unfavorable attitude towards the use of rammed earth materials to a certain extent. The community, as a carrier, fully embodies the value of modern rammed earth materials.

"Ternary mutualism" - perspective of human elements. Modern rammed earth materials are the charm window of a unique cultural community. Characteristic cultural community, where is the characteristic? The history of rammed earth, the time imprinting of rammed earth, the culture introduced by rammed earth would intangibly affect the lives of residents. As a traction line, modern rammed earth materials integrate the residents' customs and local cultures in community construction, demonstrating their different charms. At the same time, this interpretation of the characteristic culture will also be a major breakthrough.

Characteristic cultural communities play a role in protecting and continuation of modern rammed earth materials. Some of the older generation of residents said they were reluctant to abandon the rammed earth houses. Even though there are still areas where improvement is needed, the experts and teams are always looking for better ways. Things are always developing in the process of inheritance. The modern rammed earth community as the carrying body, because of its existence, can continue to encourage the use and development of modern rammed earth materials, and protect the continuation of traditional soil-building systems.

"Ternary mutualism" - perspective of technological measures. Modern rammed earth material is a practical platform for the characteristic cultural community. The creation of a distinctive cultural community is certainly not just the use of modern rammed earth materials, but it is constructed in a variety of ways. However, ramming the soil is also a verb that is more representative of the residents' participation in interaction, can truly be people-centered, and has become a model for community building, demonstrating the feasibility of building communities using modern rammed earth materials and providing a platform for teaching, learning, and using.

Characteristic cultural community is as a multiple innovation of modern rammed earth materials. With the continuous development of society, technical means have become more humanistic and more diversified. To build beautiful, livable communities, reset or refine the use of modern rammed earth materials, add new elements and discover new creative expressions to follow the needs of people
today. From the technical level, it is possible to promote more possibilities and innovations in the use of modern rammed earth materials.

3.5. Beautiful Rural Cultural Community Construction Path

Space Shaping - Optimizing the Pattern. Throughout the construction of the community, the principle of effective use of space and rational organization has been adopted, and spatial overall planning has been carried out through the addition of rural public spaces, the provision of public service facilities and the grooming of village houses. At the same time, it combines the natural resources such as clouds, water, forests and soil in the village to promote the formation of surrounding public spaces and optimize the spatial relationship of the community.

The structure of modern rammed earth houses is optimized to ensure the necessary living space and entertainment space. Residential living space can be divided into public space and private space. Cut off large space, open a small space, make full use of the floor height to divide or overall design, make slight differences in the interior space, create a space of taste and place atmosphere to meet the residents' basic living needs and communication needs[11]. At the same time, enriching the level and function of the rammed earth wall with a small node space is a feasible way for the effective use and clever reorganization of the rammed earth wall.

Textures - New Aspects of Rammed Earth. With the use of modern and diverse technologies, the processing methods of modern rammed earth walls have also been gradually enriched. Their unique textures such as horizontal stratification, graininess on the surface of the rammed earth and staggered expression of different soils have become a source of inspiration for innovative practices in the eyes of the builders. On the basis of the natural texture of rammed earth materials, changes in color, pattern, texture, etc., can add natural interest, and at the same time improve the potential advantages of modern rammed earth materials.

In the color visual performance, the color can affect people's psychological feelings, so from the residents' psychological perception, select suitable and in line with the local village style to build. Specifically, depending on the type of soil in the area, a mixture of soils can present a complex and colorful facade effect. In China, depending on the geographical environment, the soil is usually black, brown, brown, red, yellow, gray, white, and purple. Among them, the loess in the northwest region, the red earth in the Yunnan-Guizhou region, and the seven-color soil in Zhangye, Gansu Province [8], while the terracotta house in Songyang County of Lishui, Zhejiang Province is called the “Golden Potala Palace”. Another way to change the color of rammed earth is to use color additives. Based on this, we can continue to strengthen the characteristics of the stratification of the rammed earth and bring about a stronger sense of visual impact and art. It is a unique expression of the fusion of traditional elements and modern technologies.

In the texture treatment, it can increase the texture of the rammed earth wall and form the concave and convex effect, and bring the light and shadow effect of the wall surface to be full of changes. The mosaic treatment of rammed earth walls continues to be enriched and promoted by the pure characteristics of rammed soil. Stone, bamboo, tile and brick are used to achieve beautification. The mosaic treatment of the rammed earth wall continues to be enriched and promoted in the pure characteristics of rammed soil. Use stone, bamboo, tile, brick and other objects to achieve beautification. Using the good plasticity of the rammed earth wall, the pattern mold can be produced [8], which provides guidance for community display and establishment of markers.

Cultural Heritage - Continued Context. Culture is the root of the construction of characteristic communities. It deeply digs out and grasps the cultural context of the region. On this basis, it reflects regional features and national personalities through material symbols, sign symbols and commodity symbols. Ramming the soil, this traditional construction method should be treated with a critical attitude, taking its essence, going to its dross and continuing to pass on the essence, and promote development through encouragement and recognition. The continuation of the external culture depends on the efforts of the architects to create a visible and sensible cultural atmosphere. Inherently, the continuation of culture requires the joint efforts of residents and construction engineers, inputting elements such as cultural landscapes, folk customs and cultural literacy, outputting special cultural products to extend the context in order to give residents a sense of identity and a sense of belonging.
4. Conclusion

People have a natural intimacy with the soil. With the development of science and technology, the emphasis on ecological protection and the continuation of traditional craftsmanship, modern rammed earth materials are a unique expression of the characteristics of the construction of cultural communities. With its ecological purity, it can be well integrated into the surrounding natural environment and has great advantages and potential in creating a harmonious and consistent rural landscape. However, this does not mean vigorously advocating the development of modern rammed earth houses, but hoping to use modern rammed earth materials as a guide to provide a feasible and valuable road for the creation of a beautiful countryside cultural community, with a view to contributing to the preservation and inheritance of traditional culture.

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