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Exploring the Potential of Modern Rammed Earth Materials in Enhancing the Aesthetics and Sustainability of Rural Community Construction: A Case Study of Duniyapur, Punjab

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Abstract

Earthen materials have been an integral part of the growth of rural dwellings for thousands of years. However, with the homogenization of architectural styles and the lack of cultural atmosphere in the construction of beautiful countryside, the development and application of modern earthen materials have become increasingly important for the future construction of rural communities. This research paper focuses on mud dwelling houses in rural areas of Punjab and constructs a liveability evaluation system to analyse the residents' satisfaction and optimize modern earthen dwelling houses. From the theoretical perspective of "Ternary mutualism", this paper proposes that the relationship between modern earthen materials and rural communities is mutually beneficial. Modern earthen materials serve as the natural foundation, charm display window, and practice platform of rural communities, while rural communities embody the value of modern rammed earth materials, protect their continuation, and promote multiple innovations. Based on this, the paper proposes a construction path of modern earthen materials in rural communities to provide reference for future construction. The research results show that modern earthen materials are conducive to the construction of rural communities in harmony with the natural ecological environment of the local landscape and play a significant role in the protection and inheritance of local culture.

Keywords: Continuous improvement; Rural communities; Livability evaluation; Earthen communities; Sustainable landscape; Sense of identity

Introduction

Soil is a widely used material in Pakistan's traditional buildings, owing to its ecological benefits, low cost, and ability to provide cool temperatures in both summer and winter. The building technology in Pakistan has undergone several advancements and developments, including in the ancient Indus Valley Civilization and during the Mughal era. Despite the historical use of earth in construction, modern earthen materials and techniques have only rarely been adopted in Pakistan. The use of modern earthen materials has gained attention due to its sustainability, low cost, and ability to create practical and economical rural residential areas. For example, the government of Pakistan has implemented several initiatives using modern and affordable materials, for the construction of low-cost housing in rural areas [1]. However, as with many countries, the frequent homogenization of rural community construction and lack of attention to local cultural characteristics have become a concern in Pakistan. Therefore, there is a need to integrate the concept of community construction with a comprehensive focus on the human settlement environment and continuous improvement of the community planning system, while also highlighting the cultural characteristics of local communities. According to the Pakistan Bureau of Statistics, over 60% of the population lives in rural areas, and most homes are constructed using local materials such as mud, adobe, and bricks. While these materials are readily available and low-cost, they can be vulnerable to natural disasters such as earthquakes and floods. In conclusion, the adoption of modern rammed earth materials in Pakistan can not only provide a sustainable and low-cost alternative for rural housing but also contribute to the preservation and development of local culture [2]. However, it is crucial to prioritize the integration of local cultural characteristics in the construction of rural communities to avoid homogenization and promote a sense of place.

Materials and Methods

Overview of the study area

The research area is a village located in the Multan district of Punjab province, Pakistan. The village is situated at a longitude of 71.42°E and latitude of 29.19°N, and covers an area of approximately 5 sq. km. The land is characterized by flat terrain with an average elevation of 123 meters above sea level [3]. The region has a subtropical desert climate, with hot summers and mild winters, and an average annual temperature of 35°C. In this village, earthen houses are still prevalent, and many residents still inhabit them. However, there is evidence of structural degradation due to lack of maintenance, and many rammed earth walls have severe cracking and deterioration.

Data acquisition and analysis

Field observation, questionnaire survey, and interview methods were used to collect data from the village. A total of 120 questionnaires were distributed, out of which 110 were completed and returned, yielding an effective response rate of 91.7%. A livability evaluation system for the rammed earth community was developed, and the weight values of each indicator were determined to indicate their relative importance. The questionnaire data was analyzed using statistical methods, and a five-level satisfaction score was obtained for each indicator. The current situation of the rammed earth community

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in the village was evaluated using five levels, and recommendations for improvement were identified based on the community's strengths and weaknesses [4].

Results and Analysis

To evaluate the livability of earthen communities in Multan, a specific set of evaluation indices were developed. Unlike general communities, the evaluation index for the livability of rammed earth communities needed to consider the impact of rammed earth elements on the community. After conducting a literature analysis, expert review, and resident interviews, five first-level indicators and 28 second-level indicators were selected. The selected indicators were based on the principles of science, system, operability, dynamics, and typicality [5]. Using the analytic hierarchy process, five anonymous peers were invited to score the importance of each index according to the 9-point scale method. The weight value of each indicator was determined using the "yaahp V10.3" software, as shown in (Table 1). Results indicated that the housing conditions had the highest weight value as the primary indicator, followed by infrastructure, ecological landscape, community cultural environment, and social economy. The weight values of the secondary indicators varied significantly. In conclusion, the construction of the rammed earth community habitability evaluation system was based on scientific principles, and the weight values of each indicator were decided using a rigorous process. The resulting evaluation system provides a comprehensive framework to assess the livability of rammed earth communities in Multan, with a focus on housing conditions, infrastructure, ecological landscape, community cultural environment, and social economy [6].

Table 1: Determination of weight value of each indicator.

Index	Weight	Questionnaire
Social economy	0.1219	Q1-Q3
Cultural level	0.0166	Q4-Q5
Per capita income	0.0586	Q6-Q7
Household consumption level	0.0113	Q8-Q9
Industrial development	0.0354	Q10-Q15
Ecological landscape	0.1802	Q16-Q18
Greening level	0.0451	Q19-Q21
Local landscape	0.0451	Q22-Q25
Sustainability	0.0901	Q26-Q27
Housing conditions	0.3389	Q28-Q31
Planning layout	0.0255	Q32-Q33
Living area	0.0077	Q34-Q37
Structural safety	0.0991	Q38-Q41
Material use	0.0368	Q42-Q47
Auxiliary housing	0.0091	Q48-Q50
Livestock breeding	0.0151	Q51-Q52
Room temperature control	0.0087	Q53-Q57
Ventilation and lighting	0.0424	Q58-Q60
Seismic performance	0.0944	Q61-Q63
Infrastructure	0.2356	Q65-Q67
Road facilities	0.1009	Q68-Q71
Water supply facilities	0.0601	Q72-Q75
Drainage facilities	0.0404	Q76-Q78
Power telecommunications	0.0194	Q79-Q82
Sanitation facilities	0.0148	Q83-Q85
Community cultural environment	0.1233	Q86-Q88
Supporting service facilities	0.0117	Q89-Q91
Public security conditions	0.006	Q92-Q95
Neighbourhood relations	0.0415	Q96-Q100
Public space	0.0117	Q101-Q103
Cultural atmosphere	0.0123	Q104-Q106
Mental belonging	0.0171	Q107-Q108
Cultural heritage	0.0229	Q109-Q110

Analysis of resident satisfaction evaluation

In the questionnaire survey conducted in Duniyapur village, questions were designed based on the evaluation indicators of the earthen community's livability [7]. The residents were asked to rate their level of satisfaction using a rating scale that included very satisfied, more satisfied, basically satisfied, less satisfied, and dissatisfied. A total of 120 valid questionnaires were collected and analyzed to evaluate the residents' satisfaction with the village's livability. In the village of Duniyapur, more than 50% of the residents are not satisfied with their income, indicating poor socio-economic conditions [8]. This is likely due to the lack of industrial development and cultural opportunities, leading to stagnant economic growth. However, more than 70% of residents are satisfied with the area's green landscape, highlighting the ecological beauty of the village. Additionally, residents support sustainable landscape shaping and ecological protection efforts. At the housing level, residents express concerns about the poor structural safety, seismic performance, ventilation, and lighting of earthenware houses [9]. They suggest that attention should be paid to building structure safety, material use, seismic performance, and livestock breeding. While about 40% of residents do not support continued use of rammed earth materials, approximately 20% feel satisfied and support their use, believing that there is still value in this building technique [10]. Regarding infrastructure, residents express dissatisfaction with roads, water supply, and drainage facilities, indicating a lack of basic convenience and sanitation. However, they are generally satisfied with the construction of power telecommunications and sanitation facilities. At the community cultural level, residents report high satisfaction with neighborhood relationships and public security, indicating a positive living atmosphere as shown in (Figure 1). However, more than 50% of residents express dissatisfaction with public spaces, calling for increased public activity spaces and promoting social exchange. Overall, the survey highlights areas for improvement in the socio-economic, housing, infrastructure, and community cultural environment in Duniyapur village. Addressing these concerns could help improve the overall quality of life for its residents [11].

Development of a habitable earthen community evaluation system

Rammed earth has been used for thousands of years and is an essential component in the growth of rural areas. Today, modern rammed earth materials can aid the future development of rural areas [12]. However, as rural community construction becomes more homogenized, it is crucial to reflect on whether abandoning rural elements will lead to society advancing to modernization, or if using rural elements will create distinctive cultures and enhance residents' life satisfaction. This paper proposes the concept of "ternary mutualism," analyzing the coupling relationship between three main factors: natural conditions, humanistic factors, and technical means. Natural conditions include local resources, climate, hydrology, geographic location, and living environment. Humanistic factors include customary personalities, cultural qualities, epochal factors, and aesthetic concepts. Technical means involve materials, construction capabilities, and technology levels. The foundation of a characteristic cultural community is modern rammed earth materials, which are abundant natural resources found throughout the country [13].

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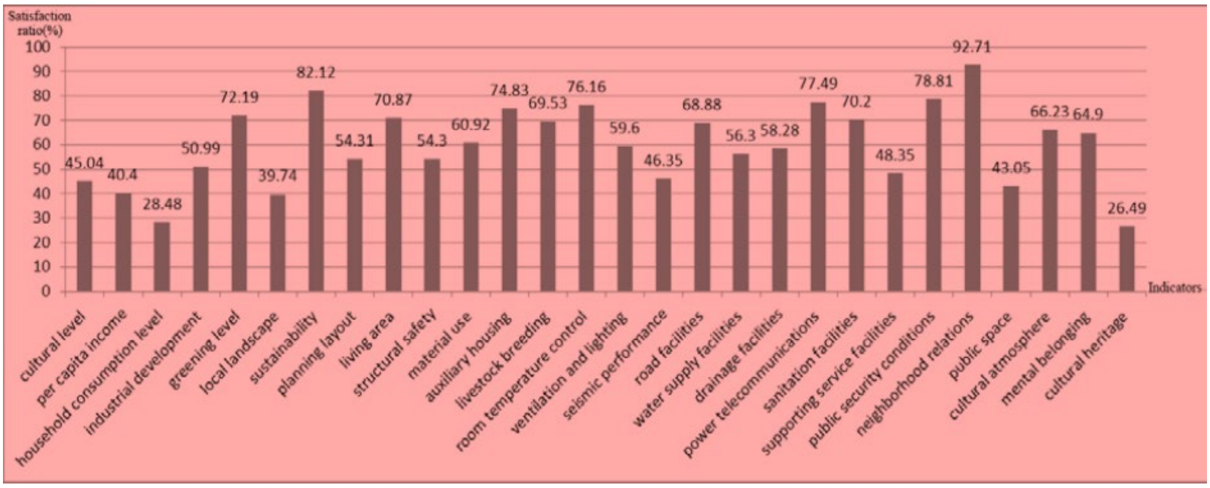

Figure 1: Residents satisfaction with relationships and public security.

Table 2: Summary table of improvement methods for structures in the earthen houses.

Component	Instructions
Foundation	Set 300-500mm brick, stone, or concrete foundation. Set moisture barrier between foundation and rammed earth wall.
Wall structure	Set wood structure column at the junction of the four corners of the rammed earth house and the inner and outer walls. Set wood ring beam 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. Arrange long horizontally pulled bamboo strips inside the rammed earth wall, and make lashings at the junction between the vertical and horizontal walls. Set up vertical pins such as short wooden sticks and bamboo strips with a spacing of not more than 1 meter in the upper and lower seams of the rammed earth wall.
Building and roof structure	Place lamellar wooden beams on the cross walls and gables for the sandwich floor structure. Fix them seamlessly to each other and connect them with horizontal wooden beams. Place a wooden pallet under the wooden purlins to reduce the local compressive stress of the wooden truss for the roof purlin structure. Set the wood wall to resist earthquake. For the wooden slope roof structure, lay the wooden rafters under the wood purlin with bamboo mat, grass mud, and green tiles.

Rammed earth materials provide a warm and ecological atmosphere, adding to the construction of communities emphasizing ecological construction and sustainable development. Modern rammed earth materials are the charm window of a unique cultural community, reflecting its history, time imprinting, and cultural influences. The use of rammed earth materials in community construction demonstrates the residents' customs and local cultures, emphasizing the importance of continuation and protection of traditional soil-building systems. The creation of a distinctive cultural community involves various construction methods, but ramming the soil is a verb that reflects the residents' participation and interaction, providing a people-centered model for community building [14]. Modern rammed earth materials provide a practical platform for the characteristic cultural community, allowing for more possibilities and innovations at the technical level. In conclusion, the ternary mutualism between natural conditions, humanistic factors, and technical means can create unique and beautiful countryside characteristic cultural communities using modern rammed earth materials [15]. The use of these materials can promote the continuation and protection of traditional soil-building systems while providing a practical and sustainable platform for rural community development.

Creating a beautiful rural cultural community: The path to success

In constructing a rural community, it is important to optimize the use of space and organize it in a rational manner. This can be achieved by adding public spaces, providing public service facilities, and grooming village houses. The natural resources available in the village such as clouds, water, forests, and soil should be incorporated to create surrounding public spaces and enhance the spatial relationship of the community. Modern rammed earth houses should be structured in a way that ensures necessary living and entertainment space. The residential living space can be divided into public and private spaces [16]. The design should make use of ample spaces, open small spaces, utilize the floor height to divide or overall design, make slight differences in the interior space, and create a space with taste and place atmosphere that caters to the residents' basic living and communication needs. A small node space should be added to enrich the level and function of the rammed earth wall, which is a feasible way for its effective use and clever reorganization [17]. Modern technologies have made it possible to enrich the processing methods of modern rammed earth walls, resulting in unique textures such as horizontal stratification, graininess on the surface, and staggered expression of different soils. Changes in color, pattern, and texture can add natural interest and improve the potential advantages of modern rammed earth materials [18]. The color of the rammed earth should be selected based on the psychological perception of the residents and the local village style. Table 2 shows Summarised improvement methods for structures in the earthen houses. The soil mixture used can present a complex and colorful facade effect. Color additives can also be used to change the color of rammed earth. Texture treatment can increase the texture of the rammed earth wall and form a concave and convex effect, bringing about a stronger sense of visual impact and art [19]. The mosaic treatment of the rammed earth wall can be achieved by using stone, bamboo, tile, and brick to achieve beautification. The pattern mold can also be produced to provide guidance for community display and establishment of markers. Culture is the root of constructing characteristic communities. It is important to deeply dig and grasp the cultural context of the region and reflect regional features and national personalities through material symbols, sign symbols, and commodity symbols. Traditional construction methods such as rammed earth should be treated critically, taking its essence, going to its dross, and continuing to pass on the essence while promoting development through encouragement and recognition. The continuation of external culture depends on the efforts of architects to create a visible and sensible cultural atmosphere. The continuation of culture requires joint efforts of residents and construction engineers, inputting elements such as cultural landscapes, folk customs, and cultural literacy, and outputting special cultural products to extend the context to give residents a sense of identity and belonging [20].

Conclusion

People have a deep connection with the soil, and the development of science and technology, along with the emphasis on ecological protection and traditional craftsmanship, has given rise to modern rammed earth materials. These materials represent a unique expression of cultural construction and can be seamlessly integrated into the surrounding natural environment, offering great potential for creating a harmonious and consistent rural landscape. However, it's important not to overly promote the development of modern rammed earth houses, but instead to use these materials as a guide to creating a feasible and valuable path towards building beautiful countryside cultural communities while preserving and passing on traditional culture.

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