

# Vanishing Traditional Vernacular Dwelling in Gully Region of Loess Plateau, China

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## Abstract

Gully region of Loess Plateau is one of the subtype regions and natural geographical units in Loess Plateau. Due to the backward economy and fragile ecology, the development of rural area restrained and even contracted for a long time. Since the implementation of construction of new socialist countryside in 2005, this region has developed amazingly. However, lack of ecological and sustainable development theory as the guideline, lots of new vernacular dwellings just pursuit construction speed and the convenience of operation, and simply copy the urban construction model, which cause the separation of rural habitats construction with regional characteristics. Based on the field investigation, this paper analyzes the development tendency of vernacular dwellings in gully region of Loess Plateau and construction situation of the newly built vernacular dwellings. Then, it summarizes the problems of vernacular dwellings during the new countryside construction. Finally, the paper analyzes the reasons of the problem. The results of this research can make up the gaps existed in the construction of new countryside, which hopes to be uses as reference in the future ecological and sustainable construction of vernacular dwellings in gully regions of Loess Plateau.

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## 1. Introduction

### 1.1 Research background

In 2005, the Chinese government put forward a conception of “Building the new countryside” (Li, 2009). In the following years, with a series of policies and projects, great changes have taken place in rural areas across the country. Loess Plateau is located in the midwest of China, which is one of the earliest human settlement and the most fragile ecological areas, covered with 30m-300m thick calcareous yellow soil (Loess Plateau comprehensive scientific expedition Academy of Sciences, 1990). It is about 530 thousand square kilometers, accounting for 1/18 of total Chinese territory (Chen, 1999).

Gully region of Loess Plateau is located in southern part of Loess Plateau, mainly refers to Wei Bei gully region, Shan Bei gully region and Long Dong gully region, including 7 cities, 18 counties, a population of about 4.3 million, a total area of about 14.8 thousand square kilometers (Zhang, 1993). Comparing to other regions in Loess Plateau, although it is full of gullies and with serious soil erosion, the broad tableland area is very suitable for farming, that also the reason why lots of towns and cities are located there and comes to a population dense area (Yu, 2007). The distribution of rural habitats in this region is dispersed and own obvious local characteristics, mainly distributed in the tableland, slope and gully (Li, 1989) (Figure 1).

Since 2008, the author began to do the research on the rural habitats development in gully regions of Loess Plateau, and join in the National R&D Infrastructure and Facility Development Program of China (2007DKA32300-12), which is a program mainly focused on the research of human settlements environment in gully regions of Loess Plateau. The author mainly did the research on gully villages in these regions. During the field investigation, review, and data analysis, the author gained a deep understanding of the influence on human settlement from regional difference.

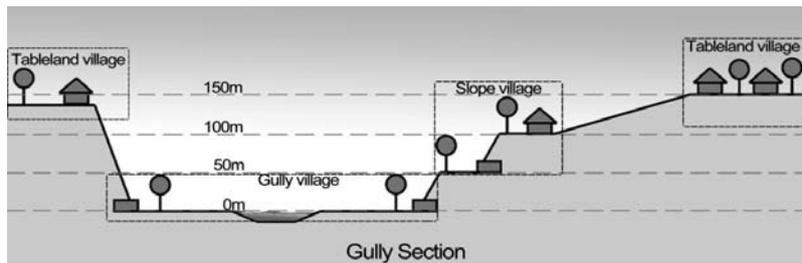


Figure 1. Habitats' types in gully region.

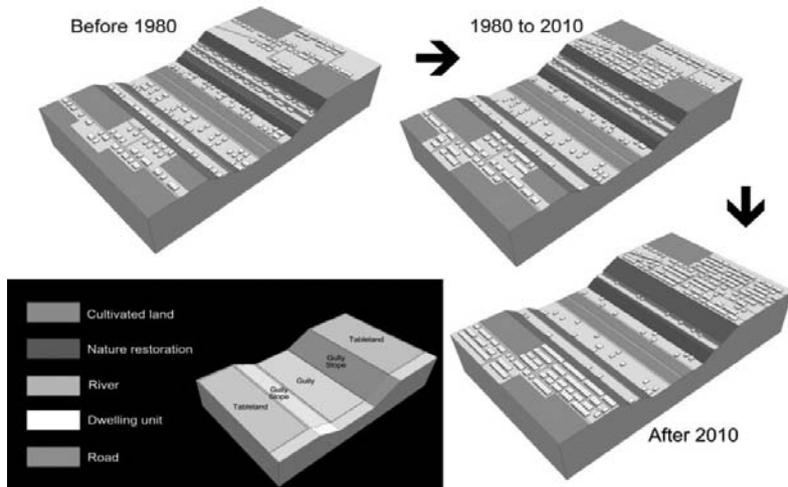


Figure 2. Schematic diagram of the phenomenon “Population move to tableland area”.

In 2011, the author participated in the science and technology research and development project of Shaanxi Province (2010K01-123), which is a research program focused on the scientific construction method of green habitats in gully regions of Weibei Loess Plateau.

In the research, it is found that during the new socialist countryside construction, large numbers of residents live in gullies move to tableland under the influence of governmental policy and residents' subjective wishes (Zhou, 2007)(Figure 2). Under the impact of exotic architectural culture, the eco-technology, traditional building materials and traditional forms that are contained in the traditional vernacular dwellings have been neglected. It leads to the traditional residential system replaced and gradually disappears.

Meanwhile, without scientific design and plan, and lacking the consideration of regional environment and villagers' living habits, the style of new dwelling emphasizes on the unity of village's facial feature excessively. So the ecological and sustainable development of vernacular dwellings in gully region comes to be the urgent priority research in the whole research of sustainable development in Loess Plateau.

### 1.2 Related definitions

#### 1.2.1 Concept category of villages' vernacular dwellings

*Vernacular dwellings* can be simply referring to the houses for residents. China owns vast territory, numerous nationalities, different customs, and living habits, thus lots of different vernacular dwellings models. The main characteristics of these vernacular dwellings are convergence and economy (Li, 2008). Convergence means that the vernacular dwellings models, construction methods, and outlooks are all tend to be the same. The economy mainly refers to the construction cost. The housing construction is mainly restrained by local people's income situation; low-cost is one of the most important influencing factors (Liang, Zhang & Lio, 2010, pp. 585-587).

#### 1.2.2 Definitions of traditional and modern vernacular dwellings

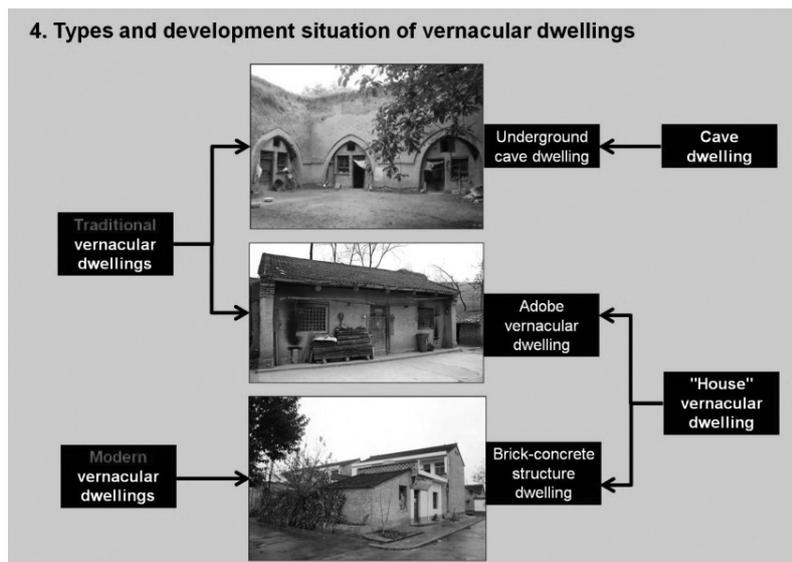
According to the development history, vernacular dwellings can be mainly divided into two types: traditional vernacular dwellings and modern vernacular dwellings. The traditional vernacular dwellings in rural habitats refer to the houses that built according to the traditional village construction methods, while the modern village vernacular dwellings refer to the houses constructed under the influence of modern urbanization and takes modern urban construction method as reference.

The traditional vernacular dwellings can be divided into cave dwellings and adobe vernacular dwellings. There are no architectural designers involved in the traditional vernacular dwellings construction, while the local artisans use their experience, knowledge, and heritage from generation to generation to design and build houses (Huang, 2014). Usually, these artisans are very familiar with local materials and climate, they can design and build low-cost houses with high suitability. The disadvantage of this kind of construction is that these artisans are all without systematic training just depend on their heritage experience and traditional construction methods; actually, it cannot keep pace with the times and meet the needs of people's modern life. Comparing with traditional vernacular dwellings, the modern one has great change in its space distribution, plan layout, building materials and construction. The modern vernacular dwellings in rural habitats refer to those brick-concrete structure vernacular dwellings (Figure 3).

#### 1.2.3 Definitions of caving dwelling and "House" vernacular dwelling

Cave dwellings are special vernacular dwelling form that just exists in Chinese north areas where people dig caves to live. Cave dwellings in the gully region of Loess Plateau can be divided into hillside cave dwellings and underground cave dwellings.

Figure 3. Types of vernacular dwellings in gully region.



The “House” vernacular dwelling shown in this research refers to the houses on the ground expect cave dwellings. It can be divided into adobe vernacular dwelling and brick-concrete structure vernacular dwelling. Courtyard as the important component is the common characteristic of these vernacular dwellings. Thus, they are also called as “Courtyard type” vernacular dwellings.

### 1.3 Research framework (Figure 4)

There are mainly three kinds of vernacular dwellings in the Loess Plateau area: Underground cave dwellings, Brick-concrete structure vernacular dwellings and Adobe vernacular dwellings. In this paper, the mainly existing problems of these vernacular dwellings are figured out by field observation and microclimate measurement. The results hope to be used as reference in the future urban construction.

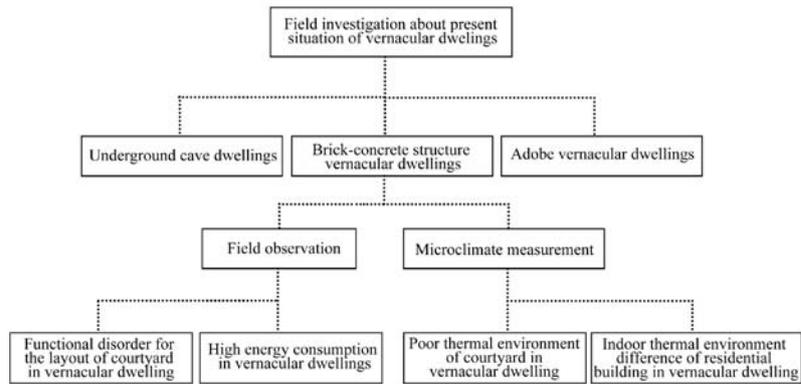


Figure 4. Research framework.

## 2. Regional characteristics of vernacular dwellings

### 2.1 Traditional thoughts about land-saving

Since the ancient times, the gully region of Loess Plateau has been a place with the contradiction that the population density is very high but the cultivable land is limited. For this reason, ancestors developed construction methods to reduce construction land and maximize the cultivated land. The courtyard dwelling on the Loess Plateau is called the narrow yard dwelling, and the unique place is the proportion of the courtyard. The length-width ratio of the narrow yard dwelling is close to 3:1 (Yunxia, 2007). It is different from most of the dwellings in northern China, the proportions of which are around 1:1 (Figure 5).

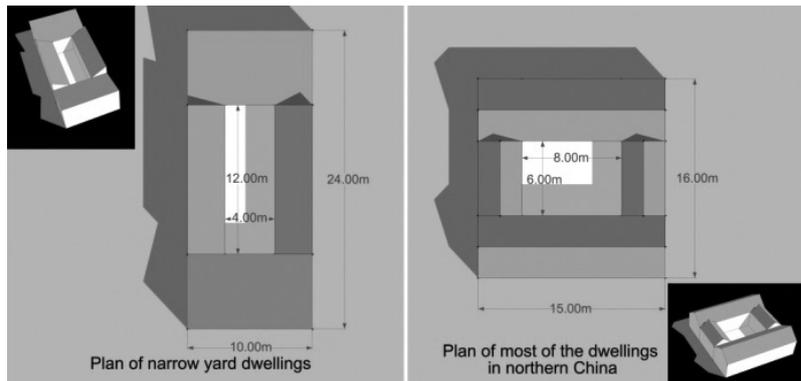


Figure 5. Comparison of the courtyard's proportion.

Compared with the same useable floor area of ordinary dwellings in northern China, the advantage of this lies in the fact that, the face width of narrow yard dwellings is narrower; it can take more dwelling units in the certain area (Figure 6). Thus, the use efficiency of useable area can be increased effectively, the village land for construction can be saved and a large number of fertile farmland can be retained through such initiatives.

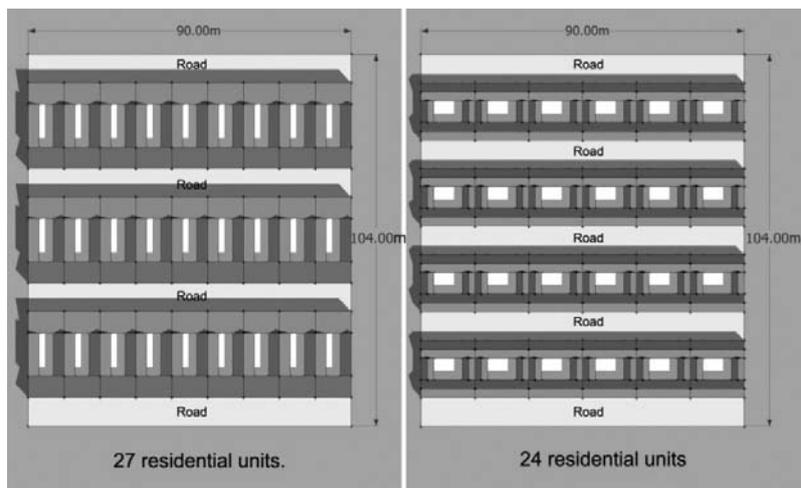


Figure 6. Comparison of units' number.

**Figure 7.** Wall made by immature soil.



### **2.2 The application of immature soil**

For a long time, as the most common material in Loess Plateau, immature soil has been widely applied to traditional dwellings. Usually, the local people make it into adobe brick and fill fiber material such as wheat straw into it to increase the strength of materials (Figure 7). The advantages of using immature soil as follows:

#### **2.2.1 Economic and environmental**

Immature soil can be seen everywhere in the gully region of loess plateau. Because of the low using cost, that makes it become a popular material (Zhao & Liu, 2003, pp. 24-25). For thousands of years, people live on it, grow foods on it, and use it to build house. The adobe house is rooted in the earth, as if it grows from the ground, blends with nature. Through long-term repeated practice by local people, it makes adobe house a kind of mature form of dwellings.

#### **2.2.2 Good physical properties**

Climatic conditions in gully region of Loess Plateau decide that the housing constructions have to take the thermal insulation and safety as the main targets. Immature soil has good physical properties such as high breathability, plasticity, and porosity, low water content, high compressive strength, and it will become increasingly strong in a dry environment (Ke & Wang, 2013, p. 12). What's more, because of its good thermal stability and sound insulation, the building made by it has a good heat preservation, heat insulation, and sound insulation performances. In addition, immature soil can adjust the indoor humidity.

### **2.2.3 Simple maintenance**

During the process of using, some damage will come out, such as dry shrinkage cracks or cracks in the wall caused by uneven settlement of the foundation. As long as it does not seriously affect the safety of the structure of the overall housing, the process of repair is very simple, the only thing needs to do is pasting the adobe cracks in the wall.

### **2.3 The influence of history and culture on vernacular dwellings**

Gully region of Loess Plateau is one of the birthplaces of Chinese civilization and several dynasties were established there. The long historical civilization forms the unique custom and has deep influence on the living, economic, transportation and diet habit, also have the effects on local vernacular dwellings' construction.

#### **2.3.1 Traditional civilization**

Gully regions of Loess Plateau located in the center of China, the capital areas for several dynasties in history, also the center of Yellow River civilization. The traditional self-sufficient farming and living style makes unique civilizations and customs (Zhao, 2004). For a long time, people are engaged in farming and own stable life, which makes the local people' characteristics are exquisite, steady and full of patience. All of these can be reflected in the local dwellings, which are heavy construction, closure, and introversion.

#### **2.3.2 Cultural accumulation**

When ancient human beings feel fear and gratitude to nature, they put themselves into the natural and try to live in harmonious with it (Zhao, Hu & Lio, 2006, pp. 335-337). The culture of harmonious with the nature and customs has long time been integrated into the traditional vernacular dwellings. In ancient China, Ritual and Ceremonious are regarded as the regulations and rules to maintain the different relationship of social classes and social orders (Xu, 2007).

They also have influence on the traditional vernacular dwellings in gully region of Loess Plateau. The layout of traditional courtyard layout can show it. The main room, as the most important building space, the room located in the middle of it is used to enshrine ancestors and as living room to do the guests' reception; and the rooms that are located on each side of the main room are the bedrooms for elders. On each side of the courtyard, the rooms are used as kitchens, storages, and bedrooms for the younger generations. Generally, the grading of east side rooms is higher than the west. All of these layouts show the traditional Chinese ethical order (Figure 8 and Figure 9).

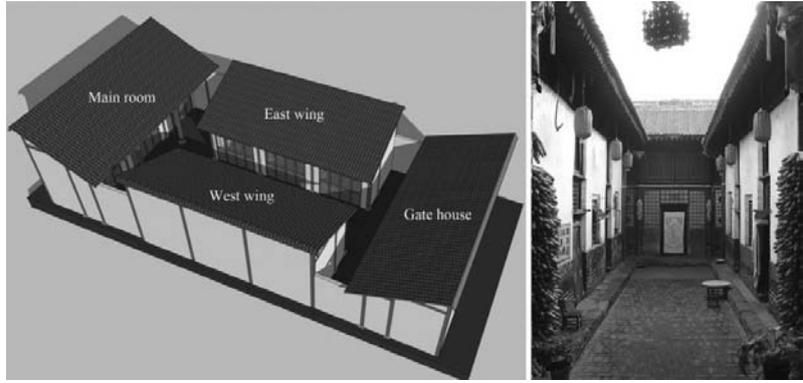


Figure 8. Space layout of traditional vernacular dwellings in gully region of Loess Plateau.

## 2.4 The influence of living habits on vernacular dwellings

### 2.4.1 Courtyard is an important living space

The courtyard is an important living and production space in the traditional vernacular dwellings of gully region, many daily activities are held there. In good day, villagers like to eat and rest in the courtyard, and women do daily housework there, such as washing, laundry, shoes' making, children also play there. What is more, as an important production assistant space, villagers usually put their farming tools there, and park farming vehicles, also they raise livestock and plant vegetables there (Figure 10).

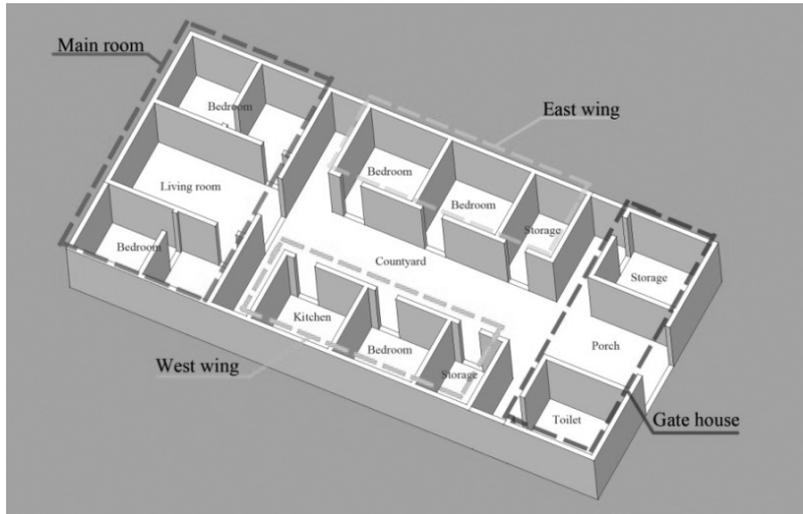


Figure 9. Division of spaces in traditional vernacular dwellings in gully region of Loess Plateau.

### 2.4.2. The design of attic space

Slope roof is commonly used in "House" vernacular dwellings of gully region in Loess Plateau, thus attics are very common there. On the one hand, attics can be used as temperature damping control areas, which has the thermal and insulation functions for the bottom space and indoor climate. On the other hand, the spacious space of attic can be used to store farming tools, grains and family debris, which is an important store space in the whole house (Figure 11).



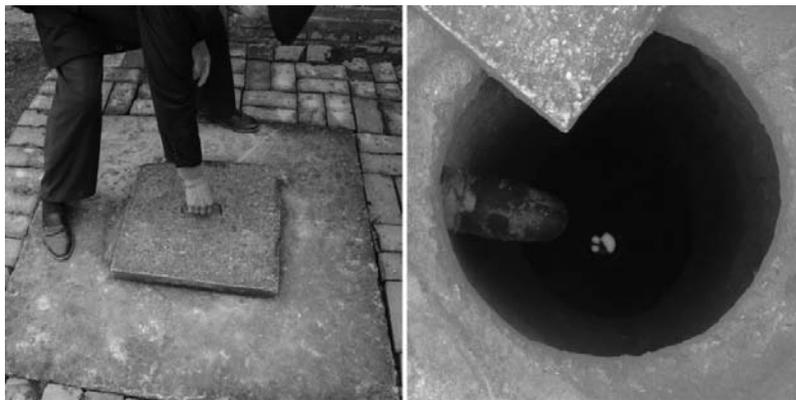
(a) South side of courtyard

(b) North side of courtyard

Figure 10. Typical courtyard in Qianyang County.



**Figure 11.** Attic space in typical vernacular dwellings.



**Figure 12.** Existing water cellar in residential courtyard.



**Figure 13.** Existing soil cellar in residential courtyard.

### 2.4.3 Water cellars and soil cellars

Water cellars and soil cellars are the wisdom crystal of the people who live in gully region in a long-term adaptation with nature. The climate in Loess Plateau is dry and lack of rain, rainwater is the main living water resource in the time without artificial welling, thus the effective rainwater collection is the important guarantee for living water usage. Water cellars are very important water storage equipment in the gully regions of Loess Plateau, which can collect and storage rainwater for the daily use (Figure 12). Currently, there are still lots of water cellars are exiting in gully region.

Soil cellar is an important storage space of food in traditional vernacular dwellings (Figure 13). In the past, there were no refrigerators, so people put food in soil cellars for long time storage. Especially, in cold winter, because of the humid and CO<sub>2</sub> in the relatively stable indoor air, the indoor temperature usually can maintain be between 0 °C and 5°C, which is suitable for storage crops.

### 3. Development situation of vernacular dwellings

In history, in order to adapt to the arid climate and make the best use of limited natural resources, local people in gully region created unique traditional vernacular dwellings forms: underground cave dwelling and adobe vernacular dwelling. However, they are on the based on backward productivity and economic conditions. Under such background, construction can only use local materials and simplify the way of building construction. With the development of the social productivity and industrialization, modern transportation and improvement of construction level easily erase the chasm. Due to the high-speed information flow, the architectural culture in the developed areas shows the influence on the countryside in gully region deeply. Brick and concrete, and those “modern” architectural materials were gradually used in the construction of vernacular dwellings, and then the brick-concrete structure start to be popular in this region.

### 3.1 Underground cave dwelling

Underground cave dwelling, the primitive and simple vernacular dwelling in gully region, is the result of thousands years' experience about human living and natural environment (Zhou, 2006). It takes full advantages of the characteristics of loess and merges harmoniously into the nature. Take the advantage of good vertical stability of yellow soil, villagers dig a square underground courtyard on the tableland, then dig horizontally to the four walls. The underground courtyard is usually called silo-cave courtyard, which is generally 9m.X9m., 9m.X12m., smaller one is about 6m.X9m. (Figure 14 and Figure 15) (Ma & Liu, 2010). In the courtyard, enough space should be left for the sewage pit, in some of courtyards, there are facilities, such as water cellars, soil cellars, milling cave, henhouses and so on.

Since the reform and opening up of China in 1980s, the original closure village opens to the outside world; the architectural culture in the developed areas shows the influence on gully region deeply. For the social improvement, economic development, more and more villagers work in cities, and heir living conception and living styles have been changed. The traditional cave dwellings are poor in ventilation and light, humid and dark, short of water supply equipment, all of which cannot meet modern peoples living equipment. What is more, in people's traditional conception, cave dwellings are the symbol of poverty. Therefore, along with the development of new countryside construction, lots of cave dwellings are abandoned, even they have many advantages, such as warm in winter and cool in summer, cheap and good for environment (Figure 16).

Since 2010, the local government initiated a project named "Three farewells", which made the requirement that all the people live in cave dwellings should be moved out within three years and the cave dwellings should be demolished to be farmland.

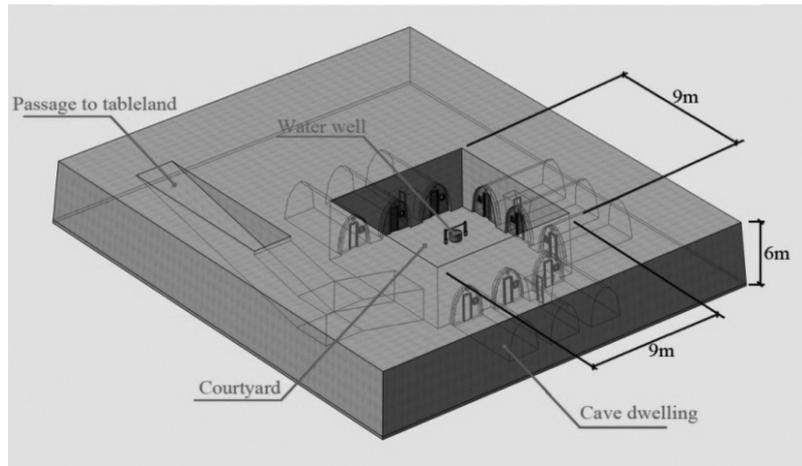


Figure 14. Structure diagram of Underground cave dwelling.



Figure 15. Underground cave dwelling example in Changwu County.

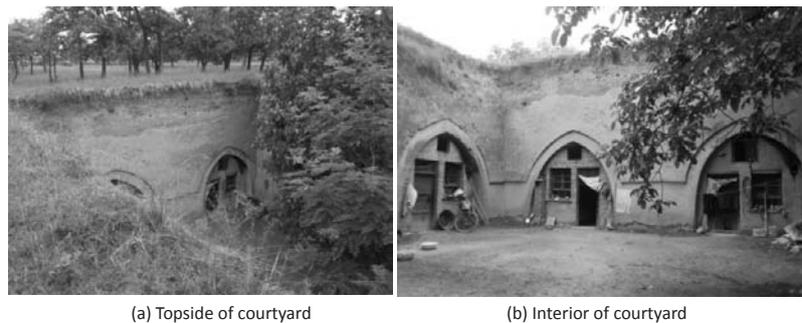
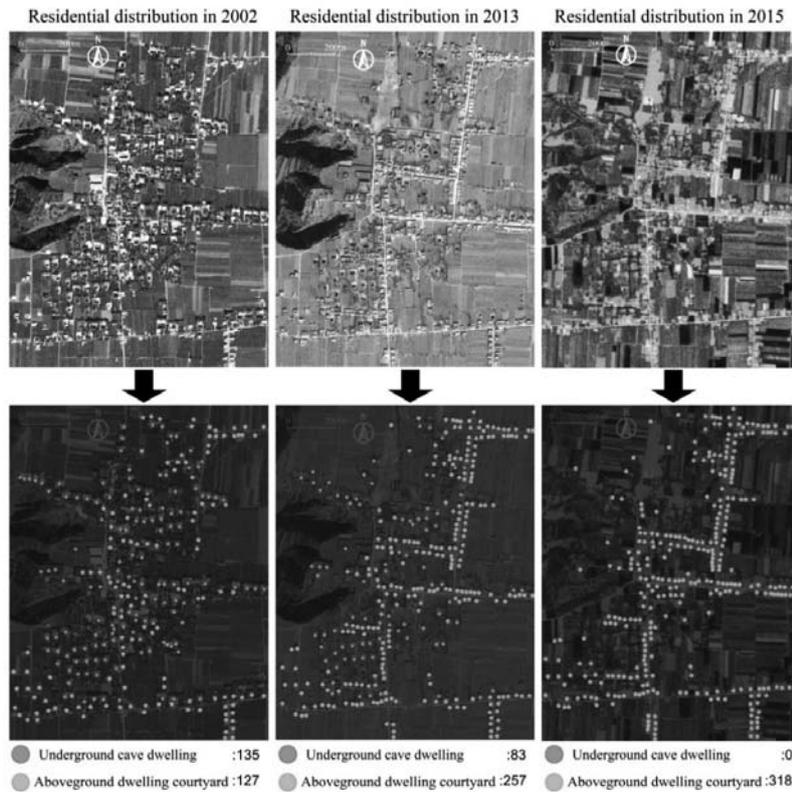


Figure 16. Abandoned underground cave dwelling in Yongshou County.

During the field investigation, just a few people still living in cave dwellings in 2014, almost all the cave dwellings disappeared, especially in gully region. The disappearance also weakens the special characteristics of local architecture.

(Figure 17) shows the change in the number of underground cave dwelling in Liang Jia Zhuang Villiage of Yong Shou County. In 2002, the underground cave dwelling takes over 50% of vernacular dwellings, while the number decreased to less than 30% in 2013. In 2014, almost all the underground cave dwellings were disappeared. Therefore, the traditional cave vernacular dwellings have already out the historical stage and cannot be established in large amount as vernacular dwelling form in the future countryside construction in gully region of Loess Plateau.

**Figure 17.** The change in the number of underground cave dwellings in Liang Jia Zhuang Village.



### 3.2 Adobe vernacular dwelling

Adobe vernacular dwelling is the typical green ecological architecture; it is characterized by proven technique, simple construction, cheap and easily available material, energy saving and ecologically environmental protection. It is widespread in the Gully Region of Loess Plateau (Figure 18).

Adobe vernacular dwelling uses immature soil to make walls and use wooden structure as weight bearing structure. Generally, the lower soil wall is related thick, which is rammed earth wall; the upper wall is thin, which is built with immature adobes. The outside of wall usually uses soil mud with forages to protect the whole wall. The traditional adobe bricks or rammed soil wall can be made by the local people themselves, the requirements of producing methods and techniques are low, and operation is simple, while the wall is very thick about 400 mm. The bottom of rammed soil wall is usually made by rubble masonry and bricks about 300 mm, which is used to prevent rain. Because of the building depth of adobe vernacular dwelling usually within 6m, the roof is generally single slope roof, which is saving construction time and materials. Column and tie construction is widely used, and raw, grass ashes are used as insulation with small gray tiles (Figure 19). Windows in the facade are less and window area is small within 1m.X1m. Windows are usually wooden frame with single layer glass, the price is low and production is simple. The building foundation of adobe vernacular dwelling is low about 600 mm. The structure is very simple, the bottom uses rammed soil and then rubble masonry, the earthquake resistant actually is very low (Figure 20).

**Figure 18.** Existing adobe vernacular dwelling in Qianyang county.



However, because of its defects, such as primitive easy to damp, limited ventilation and lighting, inadequate sanitation, the original immature soil houses is seems as the symbol of poverty and backward, few people plan to build new adobe vernacular dwelling again (Figure 21). It causes the constant decrease of these environmental protection and ecological houses, especially, during the Construction of New Countryside. Currently, the existing adobe vernacular dwelling are almost built 30 years ago, they still keep the traditional vernacular dwellings characteristic. At that time, because of the backward economy, villagers built their dwelling according to their economic ability and actual demand without unified planning. Therefore, "houses are built along one side" is very common. The doors and windows open to courtyard and distributed in a symmetrical form (Figure 22). The buildings are usually built in one line, facing to courtyard, more were built when they have enough money, such kind of layout is rather scattered.

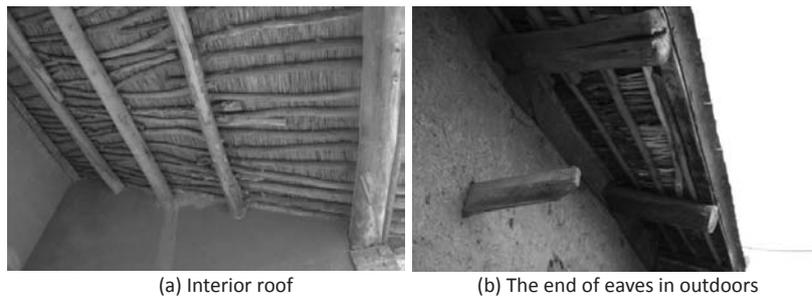


Figure 19. Adobe vernacular dwelling roof structure.

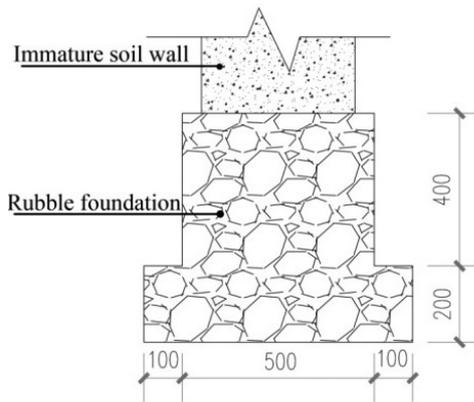


Figure 20. Diagram of rubble masonry base structure.

Through field investigation of more than 50 villages in gully region, it is found that the number of existing adobe vernacular dwelling decreased by 25% compare with 30 years ago, traditional adobe vernacular dwellings, immature soil human settlements, construction techniques are all at the edge of collapse and disappearance.

### 3.3 Brick-concrete structure vernacular dwelling

In the promotion of new countryside construction, the reconstruction amount is experiencing rapid increase in gully region of Loess Plateau. As long as the family economy allows, almost all hope to rebuild new vernacular dwellings. Brick-concrete structure vernacular dwelling is the main vernacular dwelling form developed in the process of new countryside construction. The courtyard space layout and architecture plan are mainly copied from other modern vernacular dwellings in some developed areas in China. These modern dwellings can be divided into two kinds:



Figure 21. Adobe vernacular dwelling interior.

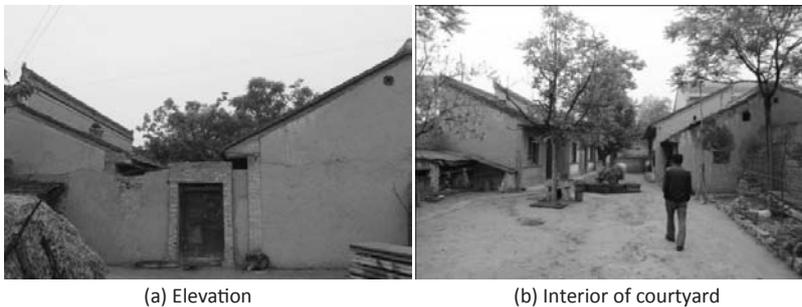


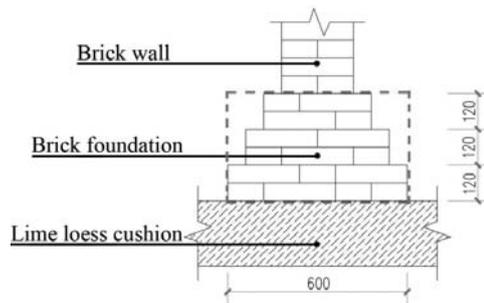
Figure 22. Courtyard layout of adobe vernacular dwelling in Chunhua County.



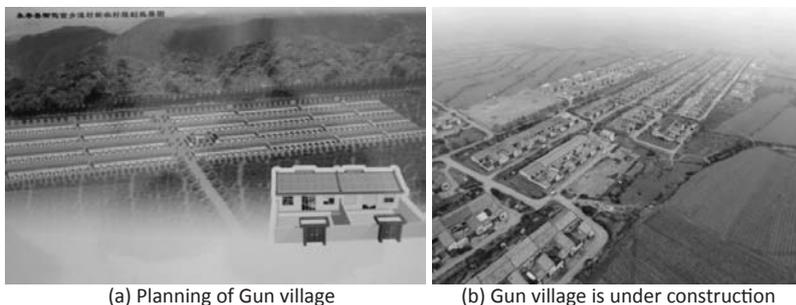
**Figure 23.** Brick-concrete vernacular dwellings.



**Figure 24.** Construction site of brick-concrete structure vernacular dwellings in Qianyang County.



**Figure 25.** Brick made base.



**Figure 26.** Massive replication of brick-mixing structure housing.

one-storey and two-storey brick-concrete structure vernacular dwelling (Figure 23). Because of the backward economic conditions, most of local villagers' income is less than 10,000 RMB/Y (1500 USD); thus, the high-cost two-storey dwellings are less. One-storey brick-concrete structure dwelling is the main house style and put as the unified architectural form in the construction of demonstration villages during the new countryside construction.

Comparing with the traditional adobe dwelling in gully region of Loess Plateau, brick-concrete structure dwellings have the advantages of tense space layout, spacious indoor, sturdy structure, and nice appearance and so on. The construction methods and materials are similar to urban houses' construction, concrete and 240 mm bricks are the mainly used materials, outside yards' walls are uncovered, the facade of architecture is generally white ceramic tiles, inside walls use cement mixed with sand, there are no insulation layers for the walls and roof (Figure 24). The inside space also has great changes; the room size is more suitable than before. It is usually 3.9m.X5.1m. The windows are larger about 1.6m.X1.8m., which provides enough natural lightness and better ventilation. The entrance doors are usually metal frame, and inside doors are made of wood. Some new and cheap passive energy techniques and cleaning energy are gradually used, such as solar power, methane and so on. The base of brick and concrete houses usually use lime-loess foundation, the proportion is 3:7, 30% lime and 70% soil, and bricks are used on the top of it (Figure 25).

However, building the new house takes large amount of land resource, and most of new houses ignore the relationship between houses and surrounding environment, without scientific design and plan, the style of new residential buildings emphasizes on the unity of village's facial feature excessively leads to architectural form monotonous and rigid, and courtyard layout unreasonable (Figure 26). Meanwhile,

interior space division mainly copies the modern houses, lacking the consideration of regional environment and villagers' living habits.

Because of the blind pursuit of the construction speed, ecological design and energy saving measures are completely neglected in the construction, making the heat preservation and insulation effect of house cannot meet the requirements. Thus, people put more money and resources in the winter heating. What is more, the poor construction technique and the lack of relevant technical guidance cause the construction quality is generally poor (Figure 27). What is more, as the main building material, clay brick is used as that is cheap but not environmental protection. Firstly, the production process of clay brick needs to consume a large number of soils, which destroys the vegetation cover of earth surface and increases the soil erosion. Secondly, because the clay bricks cannot be biodegradable, when the house is demolished, it will also pollute the environment. Thirdly, the waste dregs, gas, material and water cannot be treated well, cause serious influence on the surrounding environments.

#### 4. Main problems in the construction of vernacular dwellings

According to the field investigation, the research chooses the largest amount and the typical vernacular dwellings in gully region, brick-concrete houses, as research objective to analyze the main problems existed in the construction vernacular dwellings during the new countryside construction.

##### 4.1 Poor thermal environment of courtyard in vernacular dwelling

As the development of modern meteorology, Landsbur defined that the temperature and humidity of the area near edge land are influenced by vegetation, soil, and landscape; it is actually a kind of microclimate research,



Figure 27. Poor quality of the brick-mixing structure housing.

the land microclimate (Lu, Li & Yu, 2013, pp. 15-16). Courtyard space in the vernacular dwelling belongs to the microclimate research scope; the courtyard should have the functions of adjusting thermal environment, preventing wind and sand, and creating a comfortable living environment. For villagers, courtyard is the important productivity and living space, thus the comfortable of thermal environment own huge influence on people's living quality.

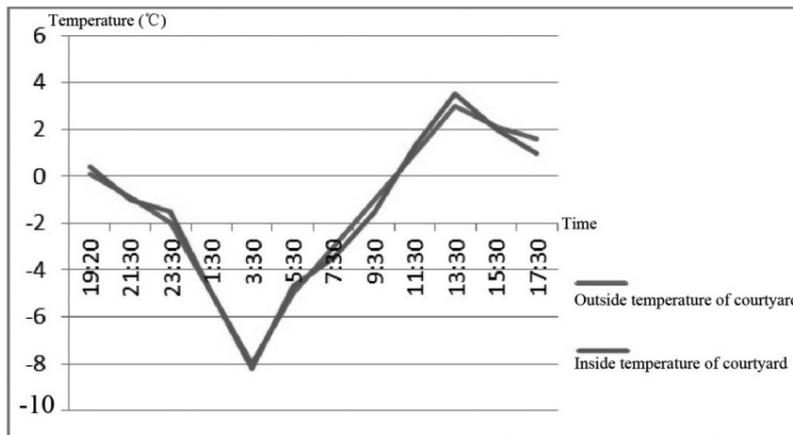
Therefore, this research selected a typical newly built Brick-concrete house dwelling in Min Feng village of Yong Shou County as research objective to research the thermal environment conditions of courtyard. The measuring time main divided into two periods of time: days around the coldest in one year (2005.01.19; 2015.01.20; 2015.01.21) and the days around the hottest (2015.07.22; 2.15.07.23; 2015.7.24). During these days, the temperature in and out courtyard are measured in site. The measurement method is selecting an open and wide place in and out the courtyard as fixed point, using hygrothermograph to collect data every two hours and record it 12 times in one day, and the measurement was done continuously for three days. Then the data was arranged and the highest, lowest and

**Table 1.** Massive replication of brick-mixing structure housing.

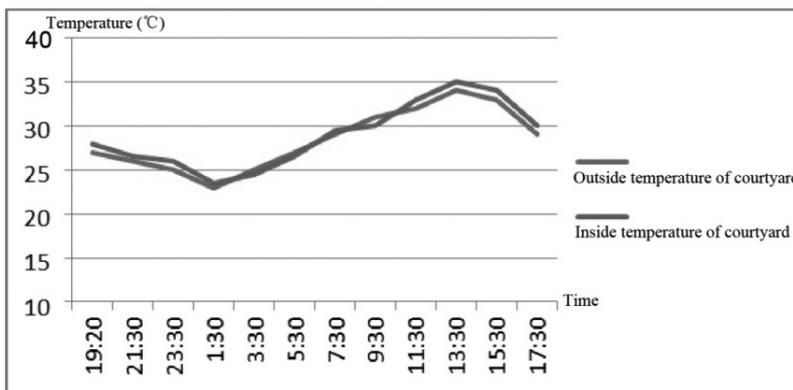
Measurement points	Highest temperature	Lowest temperature	Average temperature	Average humidity
Inside courtyard	3.5°C	-7.9°C	-4.5°C	51%
Outside courtyard	3.1°C	-8.3°C	-4.7°C	49%

**Table 2.** Thermal environment in and out courtyard in July, 2015.

Measurement points	Highest temperature	Lowest temperature	Average temperature	Average humidity
Inside courtyard	35.1°C	23.4°C	27.8°C	66%
Outside courtyard	34.6°C	22.6°C	27.4°C	63%



**Figure 28.** Temperature graph in and out courtyard in vernacular dwellings, January, 2015.



**Figure 29.** Temperature graph in and out courtyard in vernacular dwellings, July, 2015.

average temperatures within one day were got (Table 1), (Table 2), and diagram was made by the average temperature of each measurement time (Figure 28), (Figure 29).

According to the field investigation, it is found that the temperature and humidity in and out courtyard are almost the same in both winter and summer. Although there is courtyard there, the thermal environment actually is almost the same in and out it. Courtyards actually have no functions for adjusting the thermal environment, there are some problems in the design of courtyard and its thermal environment should be further researched and improved.

#### 4.2 Functional disorder for the layout of courtyard in vernacular dwelling

Vernacular dwellings' courtyard in gully region has the functions for both productivity and living (Table 3). Inside the courtyard, there are lots of living activities, such as chatting, getting shadow, washing and laundry and so on; also there are some productivity activities, villagers store their farming tools, park farming vehicles, dry grains, or build rooms for livestock there.

Currently, productivity and living, these two different functions are overlain together without good design in most of the newly built vernacular dwellings, which cause the disorder between different functions and inconvenience (Figure 30).

### 4.3 Indoor thermal environment difference of residential building in vernacular dwelling

During the field investigation, low temperature indoors in the winter is the common problems in both brick-concrete structure house dwellings and adobe vernacular dwellings. For the newly built brick-concrete structure dwellings, the indoor thermal comfort is much worse than adobe vernacular dwellings. This research selected a newly built typical brick-concrete structure house dwelling and a typical adobe vernacular dwelling in Yu Jia Gong Village of Yong Shou County as research objective. The measuring time main divided into two periods of time: days around the coldest in one year without heating system (2005.01.19; 2015.01.20; 2015.01.21) and the days around the hottest (2015.07.22; 2015.07.23; 2015.07.24). During these days, the indoor temperature was measured, the highest, lowest and average temperature and humidity in one day can be got from the measurement data (Table 4 and Table 5), and diagram was made by the average temperature of each measurement time (Figure 31 and Figure 32).

It is shown that the average outdoor temperature is -5.6°C within the three measurement days, the indoor average temperature and outdoor temperature are not very different in both vernacular dwellings, the adobe dwelling is a little higher than brick-concrete structure dwelling. Overall, the indoor thermal environment is too cold. In July, the average outdoor temperature is 28.0°C. In adobe dwelling, average indoor temperature is 24.3°C, while the brick-concrete structure dwelling is about 26.5°C, the indoor temperature is clearly influenced by the outdoor temperature and the fluctuation is related big. Generally, the thermal comfort in adobe dwelling is better than brick-concrete structure dwelling. For the indoor humidity, adobe dwellings are more stable than brick-concrete structure dwelling.

Courtyards' functions	Contents
Living activities	Relaxation
	Laundry
	Parties
Productivity activities	Cultivation
	Drying grain
	Planting
	Vehicle parking
	Storing

**Table 3.** Functions and activities in courtyards.



**Figure 30.** Temperature graph in and out courtyard in vernacular dwellings, July, 2015.

**Table 4.** Indoor and outdoor temperature in vernacular dwellings, January 2015.

Type	Highest temperature	Lowest temperature	Average temperature	Average humidity
Indoor temperature for brick-concrete structure dwelling	1.9°C	-8.2°C	-3.9°C	50%
Indoor temperature for adobe dwelling	2.3°C	-5.1°C	-3.0°C	53%
Outdoor temperature	2.7°C	-9.2°C	-5.6°C	46%

**Table 5.** Indoor and outdoor temperature in vernacular dwellings, July 2015.

Type	Highest temperature	Lowest temperature	Average temperature	Average humidity
Indoor temperature for brick-concrete structure dwelling	31.8°C	17.4°C	24.3°C	58%
Indoor temperature for adobe dwelling	29.1°C	17.6°C	26.5°C	56%
Outdoor temperature	35.2°C	21.3°C	28.0°C	61%

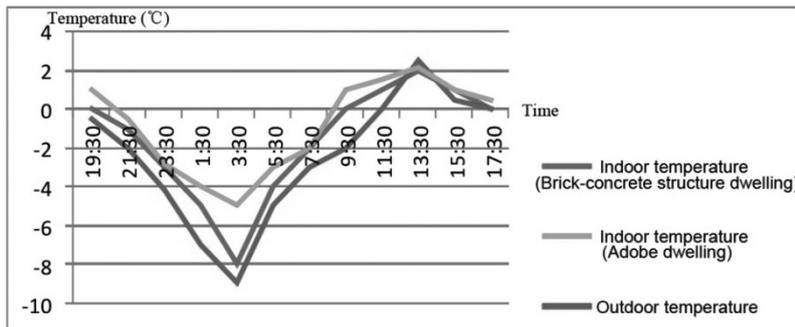


Figure 31. Indoor and outdoor temperature graph in vernacular dwellings, July 2015.

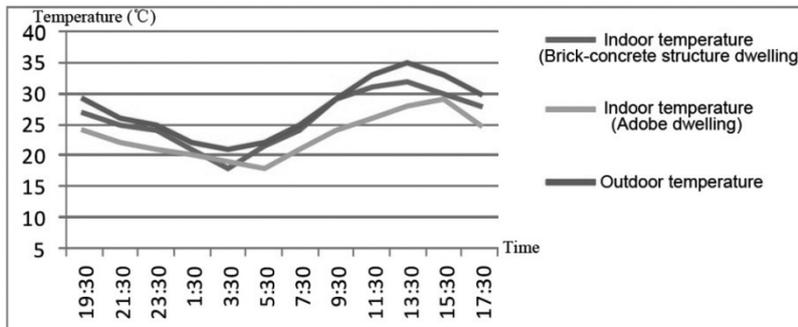


Figure 32. Indoor and outdoor temperature graph in vernacular dwellings, July 2015.



(a) Straw stacked outside the courtyard

(b) Fuel wood stack inside the courtyard

Figure 33. Traditional biomass fuels in gully region of Loess Plateau.



(a) Traditional kitchen oven

(b) Electric cooker

Figure 34. Indoor and outdoor temperature graph in vernacular dwellings, July 2015.

During the field investigation, more than 90% local people think it is very cold indoor without heating facilities. Less than 30% local villagers think it is very hot without any refrigeration facilities, while most villagers think the high temperature in summer just a few days and does not reach the intolerable level. Thus just a few people install refrigeration facilities in their houses. Therefore, compare with summer, thermal comfort conditions in winter is worse in vernacular dwellings of gully region.

#### 4.4 High energy consumption in vernacular dwellings

There are many energy types in gully regions of Loess Plateau, including coal, gas, electricity, biomass energy. Heating, cooking, and lighting are the main types for daily use. Traditionally, biomass fuels, such as straw and wood, these recyclable fuels are mainly used for cooking and heating in gully region of Loess Plateau (Figure 33).

Kitchen oven is usually made by soil or bricks. The biomass fuel they use is cheap and recycled, and when the chimney takes out the smoke, the smoke heat can increase the indoor thermal, but its inefficient burning and the ashes happened during burning will affect air quality. Currently, electric cooker and electric frying pan are more and more popular, but the traditional cooking oven are still kept and widely used. Villages are usually combining these two kinds of cooking together (Figure 34).

The traditional heating system in gully regions is “Kang”, a traditional warm bed, used in bedrooms in winter. Currently, about 60% villagers still use this traditional “Kang” for heating in winter, it used as beds indoors with a hole on the outside wall, which is used for filling firewood. In addition, the smoke goes outside by using chimney (Figure 35).

For those families without “Kang”, coal stove and other modern heating facilities are widely used. Such as electric hot air fans, electric stove. Generally speaking, the thermal comfort in the room with “Kang” is better than using other heating facilities. According to the interview with local residential, the average heating for “Kang” is twice one day in winter, and the coal consumption is about 1.8t with other assistance fuels, such as straw and wood. Recently, the demand for electricity is increased rapidly and comes to be one of the main used energy for local villagers.

**5. Reasons for existing problems in the construction of vernacular dwellings**

**5.1 Low heat storage capacity in courtyard**

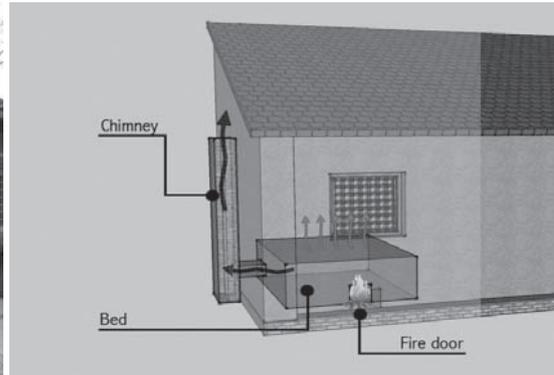
Actually, courtyard owns two functions for dwelling in gully regions of Loess Plateau: productivity activities and living activities, but for the newly built vernacular dwellings, the functional space division in most of them are not clear, just put all the functions in courtyard without design, thus cause the courtyard layouts in disorder. Materials used for floor in the courtyard are usually concrete, bricks, which are hard surfacing materials. This kind of floor materials is convenient for human activity, but heat accumulation capacity is low and the temperature increase speed is fast, which cannot supply a stable thermal environment. Wind environment does not put into consideration when construct courtyard there, villagers just build high walls according to their experience without think about the scientific wind preventing methods.

**5.2 Poor air tightness and no insulation layers in residential buildings**

Through the comparative study of traditional indoor temperatures for adobe dwelling and brick-concrete structure dwelling, it is found that the indoor thermal environment comfort in not satisfying in both dwellings, but the insulation capacity of adobe dwelling is better than brick-concrete structure dwelling, and the indoor



(a) Outlook of “Kang”



(b) Structure of “Kang”

**Figure 35.** Traditional heating facility “Kang”.

temperature in adobe dwelling is relatively stable. The reason is that, in brick-concrete structure house, the exterior walls are made from 240 mm bricks with cement plaster, roof is covered by tiles, and there are no insulation layers, thus the heat insulating capacity is very low. On contrary, adobe dwelling uses better insulation earth to build walls, while the total air tightness and indoor comfort is seriously affected by the simple construction methods and original structure. The poor insulation capacity actually increases the energy consumption, especially the energy consumption for heating.

**5.3 Inadequate utilization of energy and the usage of pollution energy**

As the development of socialist new countryside construction, people’s living standards improved a lot, at the same time, the energy consumption demand is also increased. Currently, the energy usage method is still in its original step, which causes the inefficient energy transforming. For the biomass energy like straw and wood, the burning efficiency is just about 20%, the insufficient burning also causes air pollution and lots waste. Coal and electricity belong to commercial energy, and most of Chinese electricity comes from thermal power generation. The increased use of these two nonrenewable fossil energy, on the one hand, it will cause the dependence on it, on the other hand, will cause the air pollution.

#### **5.4 Economic factors and villagers' comparing psychology restrain the ecological construction of vernacular dwellings**

At present, the rapid development of gully regions in Loess Plateau makes people over pursue the economy, and gradually they use economic situation to evaluate people. Dwelling's luxury or not is the most direct mark to show the economic situation of the family, this actually largely influence their housing construction requirements. The comparison psychology makes lots people build new dwellings to show their economic situation, also this is the motivation for some people they work and earn money in cities and build new dwellings in countryside. Usually, these new dwellings are just with luxury appearances and the architecture itself might not be putting into consideration. Thus, most of them with high-energy consumption, low environmental protection, simple structure, and poor construction appeared in the villages. Meanwhile, many villagers like to follow the tendency and copy others for the format, plan layout; materials and construction methods without thinking their own requirements and reality. The real background of this blindly following trend is the cultural and thought poverty of the local people, even the economic level of them improved (Ma & Liu, 2010, 54-58).

### **6. Conclusion**

#### **6.1 Main research conclusion**

Rural habitats in gully regions of Loess Plateau are the important carrier for the local social development. The scientific construction can not only protect the ecological environment for the gully regions, but also can make the history and culture inherited, all of these will improve villagers awareness on their living environment. Through large amount of field investigations in different areas of gully region, this paper firstly analyze on the influence of culture and regional characteristics of gully region in Loess Plateau on the construction of vernacular dwellings. On the base of this, further research on the characteristics and developing situation of traditional vernacular dwellings.

The conclusion can be summarized as: (1) the regional characteristics, the influence of history, culture and living habits on vernacular dwellings are summarized to better explain about its present situation. (2) under the background of socialist new countryside construction, underground cave dwellings have already disappeared, and the number of adobe vernacular dwellings is

decreasing year by year. Instead of it, brick-concrete structure vernacular dwellings come to be the main structure in current gully region. (3) There are several main problems exist in the construction of vernacular dwellings, such as the poor thermal environment in the newly built courtyard, disordered functional layout, poor indoor thermal environment and high energy consumption. (4) Main reasons for these problems are the small heating accumulation in courtyard, and lack of consideration about the design of space functions and wind environment, poor air tightness capacity in houses, in insulation design, the inefficient energy usage and the usage of pollution energy, restrained by economic conditions and villagers' comparing psychology.

#### **6.2 Prospect of the research**

Generally, villagers are facing a series of challenges in the new countryside construction, and they cannot overcome many of these challenges; the traditional life style is in these villages are in the danger of disappearing. Currently, the model of cities helps villages to develop, that cannot find the ability of self-renew and benign development that villages owned before. What is more, because of the abandonment of vernacular dwellings, many professional craftsmen disappear, and very good traditional construction methods disappear at the same time.

During the theoretical exploration and practice of the ecological construction of human settlements in gully regions of Loess Plateau, there are still many problems to explore. However, because of the limited time and energy, there are still many things to supply and perfect. The paper hopes that by the results of this research, more researchers in the field of environment, ecology, urban planning and other related fields can be stimulated to do more research on human settlement planning in the gully region of Loess Plateau. In addition, to speed up the process of urban and rural integration in this region, this research hopes to contribute to the construction of ecological civilization and economic construction.

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## References

- Chen, Z. H. (1999). *Essay about architecture*. China: He Nan Technology press.
- Huang, Y. W. (2014). When architects meet craftsmen. *Journal of architecture*, 3, 21-22.
- Ke, M. & Wang, C. Y. (2013). Research on energy-saving strategy of the rural vernacular dwellings in northwest China. *Industrial Construction*, 4, 12.
- Li, G. S. (1989). Research on the division of semi humid and semi dry area. *Geographical society*, 21, 111-123.
- Li, J. Q. (2009). *Research and model for socialist new rural construction*. Haidian Qu, China: Chinese Academy of Agricultural Sciences.
- Li, Y. B. (2008). *Ecological experience of traditional vernacular dwellings and its application*. Shi, China: Tianjin University.
- Liang, R., Zhang, Q. & Liu, J. P. (2010). Strategy research on the ecological design of vernacular dwellings in the Chinese west northern areas under the restrain of local conditions. *Journal of Xi'an University of Architecture and Technology*, 42(4), 585-587.
- Lu, Y., Li, C. R. & Yu, J. W. (2013). Wind direction and speed outside the green architecture, *Architectural technology*, 5, 15-16.
- Loess Plateau comprehensive scientific expedition Academy of Sciences. (1990). *Division of Comprehensive Management Development in the Loess Plateau*. Beijing: China Economic Publishing House.
- Ma, H. & Liu, J. P. (2010). Research on the climate suitability of vernacular dwellings in Chinese western countryside. *Architectural energy saving*, 6, 54-58.
- Xu, X. Y. (2007). *Research on traditional vernacular dwellings in the north of Wei River of Loess Plateau*. ShangQuan China: Xi'an University of Architecture and Technology.
- Yu, H. X. (2007). *Research on the ecological theory and planning design methods in gully region of Loess Plateau*. Xian: Xi'an University of Architecture and Technology.
- Yunxia, W. X. W. (2007). Developing with inheriting— Attempt of modernization in traditional folk house in Guanzhong zone. *Huazhong Architecture*, 5, 42.
- Zhang, T. Z. (1993). *Outline of Loess Plateau*. Beijing: Chinese Environmental and Scientific press.
- Zhao, Q. & Liu, J. P. (2003). Sustenance and development of architectural culture with regional characteristics —brief illustration on sustainable development of traditional vernacular dwellings. *New Architecture*, 2, 24-25.
- Zhao, Q. (2004). *Ecological construction of traditional vernacular dwellings*. ShangQuan China: Xi'an University of Architecture and Technology.
- Zhao, X. P., Hu, H. B. & Liu, J. P. (2006). Evaluation on environmental suitability of traditional vernacular dwellings. *Journal of Xi'an University of Science and Technology*, 3, 335-337.
- Zhou, Q. H. (2006). The evolution of the structure of cities and towns in Loess Plateau in the north of Shaanxi province, and their space forms. *City planning*, 39-43.
- Zhou, R. Q. (2007). *Green architectural system and human settlements models in Loess Plateau*. China: Beijing Architectural and building press.