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Research on the Model and Design of the Solar Energy Housing of Qinghai Farmers

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***Abstract*—Solar energy is a renewable and non-polluting resource. Many buildings have been applied with the solar energy technology passively or positively. Qinghai enjoys an exceptional natural advantage to exploit the solar energy. The focus of this study is to connect the solar technology with the living space of farmers and explore the value of solar energy in the rural housing through designing and application. Starting from "solar energy" and " native soil", through integrating the solar energy, energy saving, building design, local life into one system closely, the treatise discussed the living space "upgrading" of Qinghai farmers，among which it is realized to make use of the sustainable clean energy of nature rationally and take advantage of local resources in line with specific conditions, as well as respect the local regional culture and building characteristics, boost and improve the living condition of farmers.**

Keywords—Solar building; Rural housing; Regional culture; Sustainable; Ecological

I. INTRODUCTION

A. Research background of the solar folk houses

The application of the solar buildings is based on the research on sustainable buildings As early as the 1970s, developed countries have begun research on the construction of the solar energy house, that is, the energy absorption and conversion are used to meet the residential demands for electricity and heating. Renewable resources are truly energy resources in the future, and are also ideal energy sources that cannot be used up in billions of years. America, as a developed country, has the building energy consumption accounting for 30-90% of the total energy consumption nationwide [1-2]. To cut down building energy consumption, reduce environmental pollution, and achieve a sustainable social structure, the research on the solar energy and integrated design of the solar energy and buildings, development and application of solar thermal power generation, photovoltaic power generation, solar building materials and product applications and other aspects are in a leading position in the world. The world's first solar house was built by the American Energy Conversion Institute in 1973, which was located at the University of Delaware. Such house absorbs the solar energy through its roof, then converts the solar energy into electric energy through a special equipment to meet the residential demands for lighting, heating, power supply, etc. It also stores excessive electric energy in a battery.

B. Solar energy resources in Qinghai

Qinghai Province, China, has the most abundant solar energy resources nationwide, with vast desertification land, so that the cost of power generated by new energy is much lower than that of most other regions in China. It is located in severe cold region on the plateau, the annual average temperature is approximately 3.0°C, and the demands for heating is large and most of the region is vast with a sparse population The unique advantages of the conditions have made Qinghai a pioneer in the solar energy application and photovoltaic power [3-5]. In 2009, Qinghai Government issued a policy of "Solar Industrial Development and Promotion & Application Planning in Qinghai Province" which specifies that a complete solar building industrialization system has not yet formed in China, so that in combination with the resources, area, cost, industry, market and other ad advantageous conditions of Qinghai Province and counties, it is an inevitable trend to vigorously develop design, development and research integrating the solar energy and building.

According to the data, to promote the development and construction of green buildings and solar buildings in Qinghai Province, Department of Housing and Urban-rural Development of Qinghai Province previously issued a 2015 utilization and demonstration project planning task for the green buildings and provincial-level solar energy application, including 707,000 square meters of green buildings, 1,448 passive solar greenhouses and 809 solar street lights [6]. A total of RMB 20 million was granted for special subsidy funds, including RMB 7.267 million for the greening building and RMB 12.733 million for solar energy utilization and demonstration project.

C. Solar energy utilization strategy

Now, the industrialized utilization of the solar energy in Qinghai includes four main aspects: (1) Solar heating: The solar collector can be actively used to convert the solar energy into usable heat energy which is supplied to the heating system by local residents in winter. The demonstration project of energy-saving housing in Liuhe Township, Gangcha County, Qinghai Province is an example, and the solar equipment mainly includes a solar collector, a heat storage equipment and a radiator, etc. (2) Solar water heating system: The solar collector system and water system are used to meet the demands for hot water in winter, so that the solar hot water tank is utilized and popularized in most parts of Qinghai; (3) Solar greenhouse: Various vegetables are planted in the greenhouse which is mainly covered with glass. (4) Solar power generation: There are two types of solar power

generation: one is the solar light power generation, namely a direct conversion of the solar energy into electrical energy; The other one is the solar thermal power generation, that is, the solar energy is converted into the heat energy, and then the heat energy is converted into the electrical energy. A number of solar photovoltaic power plants have been built in Qinghai Province, and the solar power generation is widely applied in traffic and landscape, as well as lawns, stair lights and others of the residences and communities in some towns.

II. Analysis of the Characteristics of Local Farmers and Herdsmen in Qinghai

A. *Life and function of the farmers and herdsmen*

Located in the western China, Qinghai Province is known as the "Roof of the World", as prominently located in the northeastern part of the Qinghai-Tibet Plateau. Local residents in Qinghai take farming and nomadism as an economic resource. Qinghai is the intersection of the nomadic people in the northwest and the farming civilization in the east. With the improvement of the social development and industrially technical level, as well as convergence and integration of multi-ethnic cultures, the dwellings of the residences have gradually formed a unique type of Qinghai local folk houses (Figure 1).

Fig. 1. Indoor Layout of the Traditional Folk House

Fig. 2. Architectural Styles of the Traditional Residential Villages

The folk houses in Qinghai have unique living functions, to meet the production method and life style for co-existence between the farming and nomadism; (1) The heavy and solid appearance and courtyard-style space layout highlight its distinctive features. The space is roughly divided into three functional areas: residence, livestock and storage; (2) For the tall and heavy rammed earth building wall, one purpose is to resist the cold climate of the plateau, and the other purpose is to survive the defensive functions due to the social and historical background; (3) The courtyard-style structure results from poor lighting and ventilation caused by a closed and regular building appearance, plus production method of irrigation farming, so the courtyard-style space has been gradually formed; The sunshine duration is long and the light is abundant in Qinghai. So grains are aired and outdoor activities are conducted on the roof of the solid building in the sunshine; (5) Every household in Qinghai has a heating stove which is used to resist the local cold weather; (6) Since ancient times, a simple local ethnic culture has been formed in Qinghai, and the construction method of using the local materials is a major living feature of the farmers and herdsmen. The rammed immature soil and woods and bricks are the main building materials to build the traditional folk houses in Qinghai (Figure 2).

Fig. 3. Architectural Styles of the Traditional Folk Houses

B. *Living space forms and materials of the traditional farmers and herdsmen*

A typical building representative of the traditional folk house in Qinghai is "Zhuang Kuo" which strongly reflects regionalism and practicality. Zhuang Kuo means actually a courtyard consisting of four tall rammed walls made up of loess and heavy and solid gates. The roof is flat, which was used to defend the enemy in the past, but now is mostly used to dry grains by the Qinghai residents. There is a local saying, namely "there is no grass on the hills of Qinghai, and there is a race on the house in Qinghai". It can be seen that the rammed walls made up of loess and straw are very strong, with good insulation performance. The Zhuang Kuo seems to be rustic

but simple, which is very suitable for local demands in Qinghai (Figure 3).

There are three main plane types involving the traditional Zhuang Kuo: The head-shaped, key head-shaped, and hand laced behind head (Figure 4). There are no direct open windows on exterior walls of the Zhuang Kuo, which enhances the insulation and air tightness of the building in winter; the middle courtyard is the only passage for lighting and ventilation of the building [7]. The interior layout of the building is consistent with the traditional living space; meanwhile, it is also impacted by the traditional ideas of Confucianism, that is, it pays attention to the geomantic theory and all ages hierarchy, with back to the south and facing the south. The house is roughly divided into main (facing north) room, southern room, wing rooms on the east and west and corner room, and the height varies from one layer to two layers (Figure 5).

The building materials are the material basis of the construction of residential buildings. The Zhuang Kuo, taking the civil structure and brick structure as the main architectural structure, is mainly made up of four major building materials: wood, immature soil, brick and straw. The wood, as a load-bearing system of the building, is often used in the internal structural framework, with good durability and pressure resistance; meanwhile, it also reflects good decoration effects. The walls are made up of immature soil, and are also added with straws, which strengthen the crack resistance ability; the bricks laid on the corners are used for moisture protection (Figure 6).

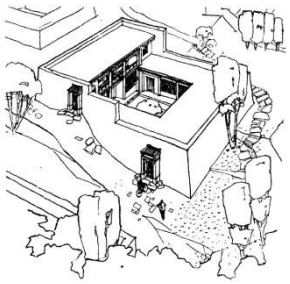


Fig. 4. Folk House Style in Qinghai-Zhuang Kuo

Fig. 5. Plane Type of Zhuang Kuo

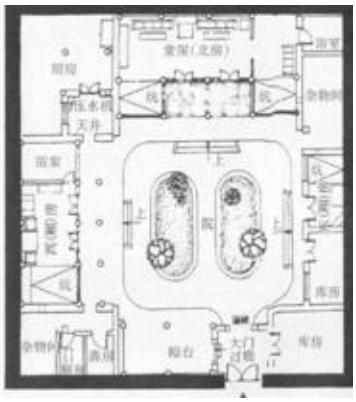


Fig. 6. Gate of the Folk House-Zhuang Kuo Fig. 7. Floor Plan of the Folk House-Zhuang Kuo

Fig. 8. Overview of Building Materials

III. Regional Planning and Solar Building Design

A. Base analysis

The research background is a plot of construction land which is located in Tuergan Village, Riyue Tibetan Township in the southwestern part of Huangyuan County, Xining City, Qinghai Province [8]. As located on the eastern edge of the Qinghai-Tibet Plateau, such construction land is a typical combined area of agriculture and animal husbandry. There are existing public roads around the site, which is designed to meet the living conditions of 15 farmers and herdsmen. Meanwhile, high-voltage line corridor in the site should be avoided.

Tuergan region of the Riyue Tibetan Township is located inland, and is classified to continental monsoon climate, with long sunshine duration and strong solar radiation. The physical data are shown in the following table (see Table 1, Table 2 for details).

Basic meteorological data

TABLE I BASIC METEOROLOGICAL DATA SHEET

Month	Air Humidity	Relative Humidity	Horizontal Day Solar Radiation	Atomospheric Pressure	Wind Speed	Land Temperature	Monthly Heating Daysy	Cooling Degree Days	Sunshine Hours
	℃	%	Kw· h(㎡· d)	Kpa	m/s	℃	℃· d	℃· d	h
January	-9.9	42.3	3.35	69.5	1.7	-9.6	846	0	213.2
February	-7.1	42.5	4.23	69.4	1.7	-5.7	702	0	213.2
March	-2.6	43.6	5.02	69.5	2.0	-0.3	624	0	239.9
April	2.5	45	5.80	69.7	2.6	5.7	457	0	239.9
May	6.8	53.4	5.78	69.8	1.8	10.2	355	4	239.9
June	10.4	59.5	5.67	69.8	1.5	13.2	234	31	266.5
July	12.6	62.9	5.80	69.8	1.2	14.8	174	79	239.9
August	11.4	66.5	5.42	70.0	1.3	13.3	198	59	239.9
September	7.1	68.4	4.47	70.1	1.6	8.8	317	7	186.6
October	1.5	62.2	4.01	70.2	1.6	3.0	497	0	213.2
November	-3.4	43.5	3.49	70.0	2.2	-2.7	623	0	213.2
December	-7.8	41.7	2.99	69.8	2.7	-7.8	781	0	213.2
Annally Average	1.8	52.6	4.67	69.8	1.8	3.6	5808	180	2718.6

TABLE II HVAC METEOROLOGICAL PARAMETERS SHEET

Parameter	Summer	Winter
Calcylating Dry-Bullb Humidity By Air-Conditioning	33	18-20
Calcylation of Wet Ball Temperature By Air-Conditioning	28	15~18
Calcylating Daily Average Temperature By Air-Conditioning	28~30	20~25
Ventilation Calculation Of Dry Bulb Humidity	30~33	17~21
Calcylating Relative Humidity By Air-Conditioning	48%	30%
Mean Wind Speed	1.7	1.75
Wind Direction	Northwest	Northwest by West

Meteorological parameters: With north latitude (36°32') and the east longitude (101°08'), and the measuring point is 3,138m above sea level.

(2) Outdoor meteorological parameters of the heating, ventilation and air conditioning

(3) Basic physical conditions

Tuergan Village is located on a hilly land, and the terrain slopes from the northwest to the southeast. With an average elevation of 3,100m, it belongs to the landform of Lajishan Mountain. There are more mountains and less land surrounding the area, with ravines and gullies, so the terrain is complex (Figure 7).

Area of construction land: Planned area≈9883m2; The building area within red line ≈5024m2 (Figure 9).

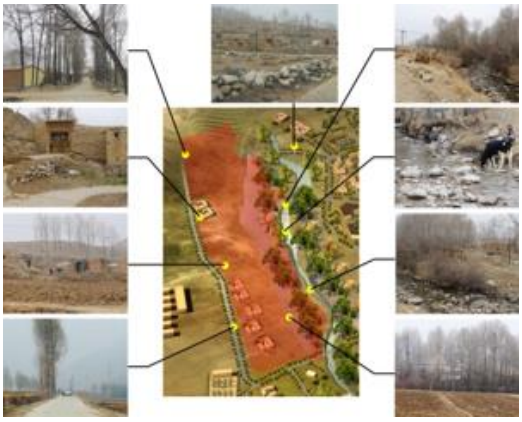


Fig. 9. Construction Site

Fig. 10. Plane of Construction Site

B. Design concept

(1) Planning concept

The planning is made around the three keywords of "block shape", "mountain shape" and "staggered" (Figure 9), and ultimately it is hoped that the building area presents the mountain situation of the Lajishan Mountain landscape; the original block shape and scale of the original building will be retained, so it has the characteristics of the traditional rural residential building. The creation of dynamic changes in the terrain of the site reflects a familiar and unfamiliar living space experience of the village. Starting from the natural environment, the preliminary structure sketch concerning the new building is drawn, based on the morphological trend of the landforms of the Lajishan Mountain in Qinghai. On that basis, a tilting trend is strengthened, a sense of modelling of the building group is enhanced, and a novel architectural style is created (Figure 10).

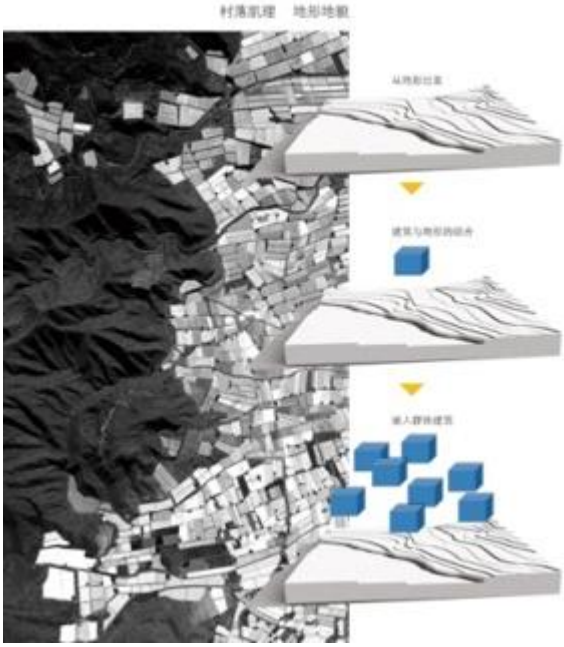


Fig. 11. Design - Concept

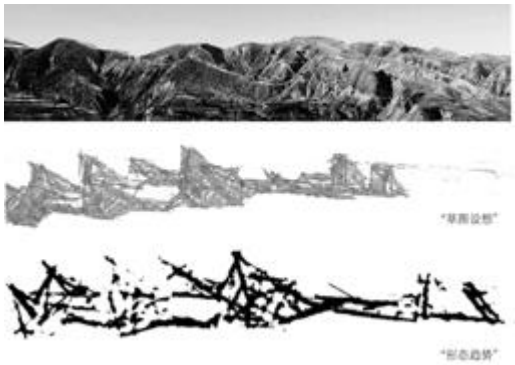


Fig. 12. Design - Sketch Design model

(2) Architectural concept

Starting with the local natural environment and the characteristics of the folk house, the new building explores the combination of the traditional culture and the modern culture. Firstly, a specific design strategy for the application of the solar energy technology to the building is made through the theoretical literature studying; the solar collector with a solar panel as one of its components is installed on the roof of the building, which is a basic attribute of the solar building. Following the local installation angle and optimal building orientation is a scientific basis for the solar building design; Secondly, the heating collection, ventilation & cooling and natural lighting are solved to the greatest extent. The functional spaces of the building are arranged based on the demands for the living and the residence of the local residents, and by using local materials, the local materials and new materials are coordinated for utilization. The base resources are absorbed and digested to plan and design the integrated space of the building landscape, which is a practical basis of this design scheme; Thirdly, the base space is built from the perspective of aesthetics, based on respecting the regional culture, inspiration

from the environment and landform, the reference of the traditional architectural forms, etc. The building change is only defined based on a place of residence, but the building may also be a beautiful landscape (Figure 11).

Fig. 13. Design model

C. Solar energy utilization strategy

(1) Village layout

In the existing base area, the framework of the traditional Zhuang Kuo is used as a unitary residential module. The size of the unit module site is (15m*15m), which is subject to a standard of meeting the living demands for the farmers and herdsmen. 4-5 houses form a living community that is reasonably distributed on the site. To maximize the utilization of solar energy resources, the overall village unit space is planned based on the optimal orientation of the building of Xining, Qingdao (23°); meanwhile, the layout of the staggered space is formed according to the height difference of the site. The block form and scale of the original building are retained in the design, so that it has the characteristics of the traditional rural houses. A new village layout is created based on the dynamic changes in the altitude difference of the terrain of the site. Figure 12: Design-Building Model (01/02/03 /04)

Fig. 14. Design - Environmental Function Layout

Fig. 15. Design - Overall Effect of the Architectural Planning

Fig. 16. Design - Building Facade Effect

(2) The solar energy utilization strategy of the building

The village consists of the residential system, the landscape system, the facility system, the greening system and the traffic system. Through basic analysis of the site and overall planning, the connection between the buildings is built, with the bridge between the spaces. As a solar building, the most important function of such building is to fully absorb and utilize the sunlight. Therefore, one side of the roof of the building is used as a lighting surface of the solar panel. Based on the optimal sun angle of 37.75°, the slope roof is designed as a single slope roof. In this way, it can not only ensure the maximized lighting effect and increase the building space, but also be used as an insulating layer of the bottom living space and the installation space of the solar energy equipment. The overall living space is equipped with the solar energy equipment to achieve the interior heating, electric power, heat preservation, etc., (Figure 13-15).

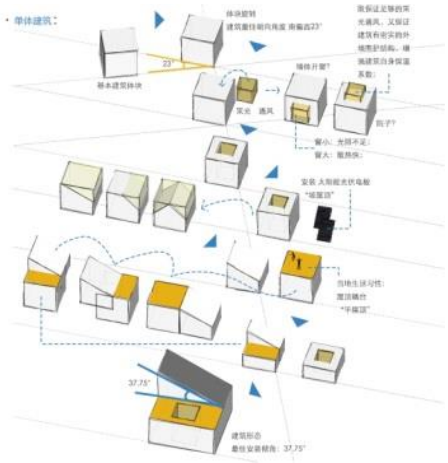


Fig. 17. Design - Planning

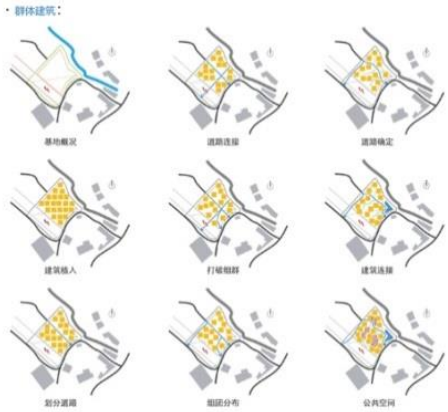


Fig. 18. Design - Single Building

The building retains the glass corridor arranged in the local traditional building - Zhuang Kuo, to be not only used as a passage connecting the various spaces, but also a transitional space between indoor and outdoor spaces. Its most of the heat comes directly from the sunlight; the solar energy is stored during the day, and it acts as a barrier between the interior part and exterior part of the building at night to slow the heat loss. The sunlight passes through the glass to directly reach the corridor area partially and also to be absorbed by the ground and wall partially. And the hot air circulation and heat conduction flows into the building to play a role of the solar heating.

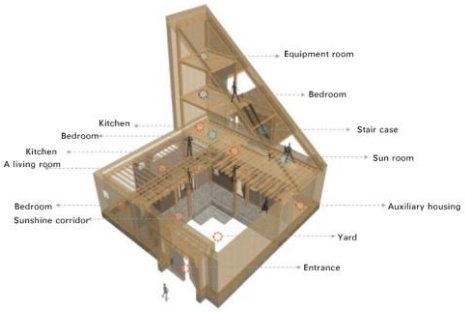


Fig. 19. Design - Functional Space1

Fig. 20. Design - Functional Space2

The windows of the building are arranged based on the function of the living space, and the façade forms a sense of rhythm changes to create a fun facade effect.

Except for utilization of the solar technology for heating and power supply demands, the building itself has good a thermal insulation coefficient, as located in a severely cold area.

Further, it should inherit the regional cultural characteristics and economic factors (Figures 16-19).

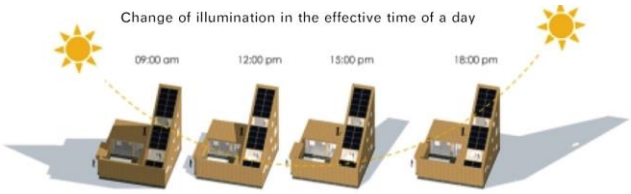


Fig. 21. Design - Sunlight Analysis of the Building Environment

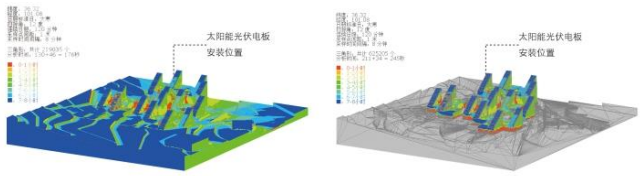
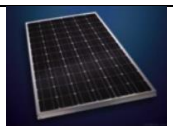
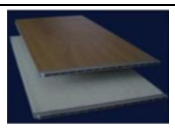
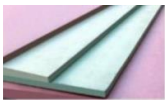


Fig. 22. Design - Sunlight Analysis of the Building Environment

TABLE III LIST OF BUILDING MATERIALS

Major Building Materials				
Material Name	Solar Panels	Wood	Local Materials	Straw
Use Area	Major Building Materials	Interior Wood Structure	Rammed Earth Wall of Building Enclosure System	Exterior Wall of Building Enclosure System
Reference Map				
Material Name	Masonry	Aluminum Allory Frame	Pvc Floor	Eps Insulation Board
Use Area	Building Facades,Steps,Paving,Land-Scape Facilities	Doors and Windows	Indoor Ground And Elevation	Wall And Floor
Reference Map				

D. Building materials

Some new building materials are also used, except that the original materials made of immature soil are retained, so that the living space is closer to the life of modern farmers and herdsmen.

Fig. 23. Architectural glass corridor and interior space1

Fig. 24. Architectural glass corridor and interior space 2

IV. CONCLUSION

Since ancient times, our ancestors have known about making full use of the nature elements-sunlight when building the house. The building is back to the south and faces the south as far as possible, which intensifies the lighting and heating of the building. The solar energy source is a good new energy before us, and also gets more and more attention. The research, development and application of the solar energy building will develop rapidly in the future construction industry. Meanwhile,

as a developing country, China's village plays a very important role in the urban systems at all levels. There are 800 million people living in rural areas in China, and the characteristics of the rural environment and the happiness index of rural residents are the important issues in the rural construction today.

For this point, it is necessary to find a crossing point between the solar building and urban housing to explore an architectural design strategy that is suitable for the abundant solar resources and highlighted regional architecture features, so that a living space regarding sunlight and natural conditions & social customs is created for the local villagers, that is, it is comfortable, sound and more environment-friendly solar housing.

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