

Cold-Formed Thin-Walled Steel in Rural Buildings in China

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ABSTRACT: In 2017, with the proposal of the rural revitalization strategy, the vast rural areas in China ushered in great development. A large number of rural construction projects began to be launched. At the same time, with the continuous development of rural society and economy, people have higher and higher requirements for the construction of rural buildings. Traditional building materials have been difficult to meet the needs of rapid construction and building comfort. People began to explore the application of new building materials in rural construction. Cold-formed thin-walled steel is gradually popularized and applied in rural buildings because of its characteristics and advantages. The article first summarizes the main characteristics of cold-formed thin-walled steel. It then analyzes and compares it with the characteristics of traditional Chinese main rural building materials. Then, the advantages of the prefabricated cold-formed thin-walled light-weight steel structure buildings constructed by cold-formed thin-walled steel are summarized. The conclusion is drawn that the prefabricated cold-formed thin-walled light-weight steel structure buildings will become the main trend of the future development of rural buildings in China.

1 Introduction

With the implementation of the rural revitalization strategy, a construction boom has been set off in the vast rural areas of China. According to the data published on the website of the National Bureau of Statistics, the per capita housing construction area in China's rural areas reached 48.9 m² at the end of 2019, an increase of 97.2% over 2000 (Figure 1). As an important part of rural construction, rural buildings are not only an important spatial carrier of rural production, life, and public activities but also an important spatial carrier of local culture. With the continuous development of rural society and economy, people's requirements for the comfort and safety of rural buildings are increasing day by day. The requirements for spatial flexibility and functional complexity of rural buildings are increasing day by day. The requirements for low-carbon environmental protection in the construction and use of rural buildings are becoming more and more stringent. There is increasing attention paid to the rapid construction and cost control of rural buildings. In this context, it is difficult for traditional building materials and construction methods to meet the needs of rural building development. It is necessary to explore the application of new building materials and construction methods in rural construction. In recent years, as a new type of building material and method, the prefabricated cold-curved thin-walled light steel structure building is being promoted and applied in rural buildings in China. It has gradually become a hot spot in the academic community. However, there is a lack of systemic research on cold-bent-wall steel in rural

buildings in China. Therefore, this article compares and analyzes traditional building materials and cold-curved thin-wall steel materials to explore the application advantages of cold-bent and thin-wall steel materials in domestic rural buildings. It also explores the application of cold-curved thin wall steel in the domestic rural building field. The development trend is analyzed in order to provide references for future rural construction development¹.

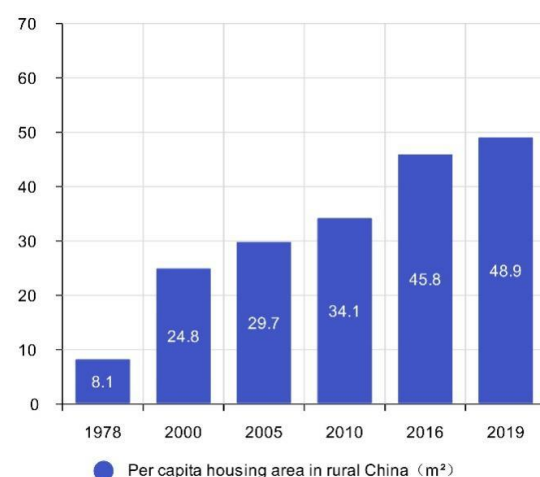


Figure 1. Per capita housing area in rural China

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2 Overview of cold-formed thin-walled steel

2.1 Cold-formed thin-walled steel

Cold-formed thin-walled steel is a finished, lightweight, thin-walled steel that bends strips or steel plates into various cross-sectional shapes such as C, U, and Z at room temperature².

2.2 Main features of cold-formed thin-walled steel

Cold-formed thin-walled steel has the main features of lightweight, high strength, good mechanical properties, recyclability, low consumption of steel in the production process, good environmental protection and economy, rich cross-sectional shapes, and strong adaptability³.

2.3 Main uses of cold-formed thin-walled steel

Due to the above characteristics of cold-formed thin-walled steel, prefabricated buildings are the main application fields of this material at present, especially in the field of low-rise prefabricated buildings⁴.

3 Chinese traditional main rural building materials and characteristics

China has a vast territory with numerous ethnic groups, rich topography and landforms, and diverse climate types. The country gives birth to a wide variety of regional cultures. There are many rural buildings in the vast rural areas of China. Their construction is mostly influenced by local natural conditions and folk customs. People generally tend to build houses with local materials. The main building materials are soil, wood, brick, concrete, etc.

3.1 Soil

In many rural areas in China, soil, especially clay, is used as the main building material. At the same time, reinforced materials such as foxtail grass, straw, and wood fiber are added to the soil to improve the bending and shear resistance of the mud walls. The houses built in this way are called adobe houses. Due to the material characteristics of the soil itself, the adobe house has good thermal insulation performance. The indoor environment is warm in winter and cool in summer. However, at the same time, it also has shortcomings such as small indoor space, narrow window opening areas, unsatisfactory lighting and ventilation conditions, and easy collapse when soaked in water.

3.2 Wood

Wood is also one of the main traditional building materials for Chinese rural architecture. Timber-structured buildings have a short construction period, strong earthquake resistance, and flexible layouts. However, large-scale promotion and application are likely to cause

damage to forest resources. At the same time, there are also shortcomings, such as poor fire resistance, unsatisfactory moisture resistance, and vulnerability to termite damage.

3.3 Brick

Brick is the most common building material in rural China. Brick-concrete structure building is the most mainstream structural form of rural architecture in China. The construction of brick-concrete structures is simple, and the cost is low. However, the brick-concrete structure has disadvantages such as self-healing, low seismic performance, and small building space. At the same time, the production of bricks will cause certain damage to the environment.

3.4 Concrete

The reinforced concrete frame structure made of cast-in-place concrete has a flexible spatial layout and good seismic performance. Nevertheless, the construction is greatly affected by the environment and season, and the construction process is relatively complicated.

4 Application advantages of cold-formed thin-walled steel in rural buildings

4.1 Shockproof and windproof

The basic structural system of the prefabricated cold-formed thin-walled light steel structure is made of cold-formed thin-walled steel. The new type of plate is supplemented with thermal insulation and decorative materials to form the enclosure structure, and the building weight can be greatly reduced. The self-weight of the curved thin-walled light steel building is only 1/3-1/5 of the ordinary steel structure building, 1/5-1/6 of the reinforced concrete structure building, and 1/9-1/10 of the brick-concrete structure building. It is precisely because of the lower building weight that prefabricated cold-formed thin-walled light steel buildings can effectively reduce the response to earthquakes. At the same time, the good ductility and plasticity of the cold-formed thin-walled steel itself make the prefabricated cold-formed thin-walled light steel structure have the characteristics of flexibility. It is different from traditional buildings that use steel to resist earthquakes, which can effectively absorb seismic energy. Therefore, the prefabricated cold-formed thin-walled light steel building can meet the fortification requirements of seismic intensity of up to 9 degrees.

The wall, roof, and floor of the prefabricated cold-formed thin-walled light steel structure building, the foundation, and the structural system are combined to form a stable hexahedron through different strong connectors. The resulting skin effect can make the light. The deformation of the steel structure system is reduced by about 15%. This greatly improves the overall structural stability, can effectively resist horizontal and vertical loads, and can finally withstand a typhoon of level 12.

Many villages are located in high-incidence areas of earthquakes and typhoons. Hence, the application of cold-formed thin-walled steel in rural buildings can effectively resist the damage of earthquakes and typhoons⁵.

4.2 Convenient transportation, short construction period and low cost

China is a mountainous country. 69% of the country's total plateau and land area are mountainous and hilly areas. Many rural areas are located in the above areas. The terrain is complex, and the rural infrastructure is not perfect enough. Farmers live scattered and provide building materials. The high-strength and low-quality characteristics of cold-formed thin-walled steel can effectively overcome this difficulty, reducing transportation costs⁶.

All structural materials and components of the prefabricated cold-formed thin-walled light steel building can be prefabricated in the factory, which can ensure the accuracy of components and reduce the construction error rate. At the same time, only prefabricated operations are required on-site. Thus, the amount of on-site construction work can be greatly reduced, and the construction period can be shortened to 50%-70% of traditional buildings. Under normal circumstances, a building below 3 floors can complete the structural construction within 5-7 days and immediately transfer to the interior decoration process. Depending on the complexity of the interior, the overall completion can be completed in 30-50 days. Coupled with the reduction of labor and equipment investment, the construction cost can be effectively reduced, and the comprehensive cost is only 70% of the traditional building. Since cold-formed thin-walled steel can be mass-produced industrially, the larger the building scale is, the lower the construction cost will be. According to statistics, China's construction steel structure output in 2020 was 81.38 million tons. At present, the steel used for prefabricated building structures only accounts for about 5% of the national steel output, compared with about 10% in developed countries. China's steel structure industry still has room for substantial growth (Figure 2). Due to the above advantages, cold-formed thin-walled steel is particularly suitable for large-scale construction in rural areas in China.

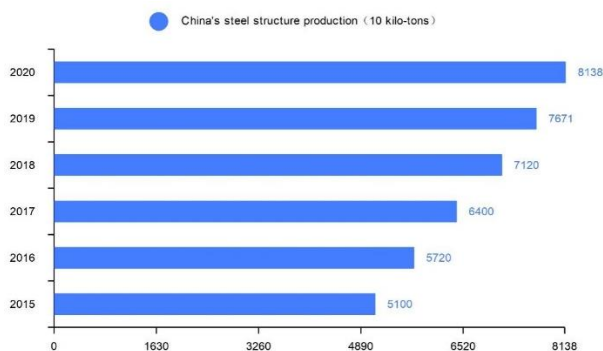


Figure 2. China's steel structure production

4.3 Environmentally friendly, comfortable and energy-saving

The prefabricated cold-formed thin-walled light steel building adopts dry operation during construction. The construction process has low noise and little dust pollution. Compared with traditional buildings, construction water consumption can be saved by 90%, and construction waste can be reduced by 80%. There will be little damage to the surrounding environment. 80% of the building materials of the prefabricated cold-formed thin-walled light steel building can be recycled, and the cold-formed thin-walled steel can be recycled 100%. Thus, it is a green and environmentally friendly building material⁷.

Prefabricated cold-formed thin-walled light steel buildings can effectively block sound transmission by filling sound-absorbing materials in composite walls composed of different thicknesses and materials, multi-layer cavities, and multi-layer structures. The sound volume can reach 50 dB and 55 dB, respectively, which exceeds the sound insulation standard of five-star hotels.

The prefabricated cold-formed thin-walled light steel building adopts high-efficiency energy-saving walls with excellent thermal insulation effect, which greatly improves the comfort of the building's indoor space. At the same time, the energy consumption becomes lower, and the wall becomes thinner. The energy consumption of traditional brick-concrete buildings can be reduced by 65%. The thickness of the outer wall with decorative layer is mostly 180 mm, which is 60 mm thinner than the 240 mm conventional brick wall without thermal insulation decoration. The usable area of the house can be increased by 5%-9%. Therefore, prefabricated cold-formed thin-walled light-steel buildings can provide a comfortable indoor environment and be used in a wide range of areas, whether it is a village in a severely cold area or a village in a hot area.

4.4 Diverse shapes and flexible space

Due to the good plasticity of cold-formed thin-walled steel, the prefabricated cold-formed thin-walled light steel structure building can be more flexible and diverse in architectural design so as to meet the different aesthetic needs of the vast rural areas. In addition, because the prefabricated cold-formed thin-walled light steel structure building adopts an overall stress-bearing plate structure system, there are almost no beams and columns in the interior space. This greatly improves the layout flexibility of the interior space.

4.5 Good durability

Through special coating anti-corrosion treatment on cold-formed thin-walled steel structures and bolts and other components, the main method is galvanizing. The conventional double-sided galvanizing amount is 180 g/m², and it can reach 350 g/m² in special cases, such as in highly corrosive environments. It is required that the amount of double-sided galvanizing reaches 275 g/m², and the thickness is about 20 μm. Through the salt spray

corrosion test, the galvanized corrosion with a thickness of about 0.14 μm is produced every year, which can guarantee a service life of 150 years. Therefore, the durability of the prefabricated cold-formed thin-walled light steel structure building is very good, and the structural safety can reach 95 years. The National Housing Research Center NAHB has conducted follow-up sampling tests on four residential buildings with light steel galvanized components located in cold and hot areas, respectively. The test results show that their lifespans can reach more than 100 years. By tracking, monitoring, and sampling 15 light-steel galvanized residential buildings located in different regions and environments, British Steel found that the average corrosion rate of components in three years was less than 0.1 μm . Compared with the average life of concrete houses of 70 years, 8 μm thick plating, the service life of zinc cold-formed thin-walled light steel structure buildings can reach 240 years under normal conditions⁸.

5 Application and development trend of cold-formed thin-walled steel in the field of rural construction in china

Due to the above advantages, cold-formed thin-walled steel is especially suitable for low-rise buildings in the vast rural areas of our country. In recent years, prefabricated cold-formed thin-walled light steel structure buildings have developed rapidly in rural areas. A complete technical system has been gradually established (Figure 3). On January 1, 2019, with the approval of the Ministry of Housing and Urban-Rural Development, the "Technical Standard for Cold-Formed Thin-Walled Steel Multi-Storey Residential Buildings" (JFJ/T421-2018) began to be implemented. At the same time, the state has intensively introduced relevant policies to encourage the development of prefabricated buildings in rural areas (Table 1). The prefabricated cold-formed thin-walled light steel structure building has a broad space for development in rural areas in China. According to the 2021 "White Paper on Consumption Data and Development of China's Rural Self-Built Housing Industry", about 5 million rural houses are newly built or rebuilt each year in China. Additionally, the rural housing market will form a trillion-level market space.

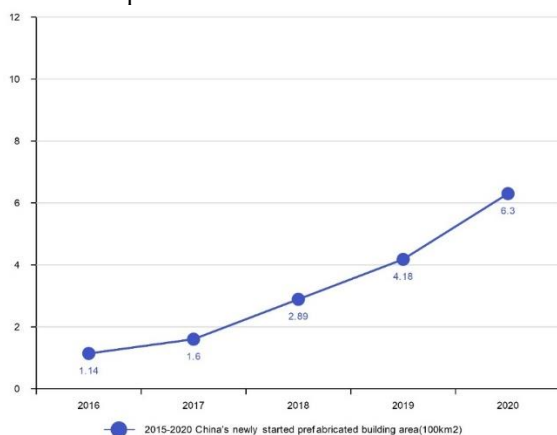


Figure 3. 2015-2020 China's newly started prefabricated building area

Table 1. China's main document to encourage the development of light steel structure prefabricated buildings in rural areas

China's main document to encourage the development of light steel structure prefabricated buildings in rural areas			
Time	Department	Document	Main content
Feb, 2019	MoHURD	Notice of the General Office of the Ministry of Housing and Urban-Rural Development on Carrying out the Pilot Work of Rural Housing Construction	Architectural application technologies such as prefabricated buildings are explored.
Mar, 2019	MoHURD	Notice on Printing and Distributing the Work Highlights of the Construction Market Supervision Department of the Ministry of Housing and Urban-Rural Development in 2019	In the reconstruction of dilapidated houses in rural areas in the pilot area, it is clarified that a certain proportion of the engineering projects will adopt the steel structure prefabricated construction method.
Jul, 2020	MoHURD	Opinions on vigorously developing steel structure buildings	The promotion and application of steel structures in farm house construction and other fields should be increased.
Apr, 2021	NPC	Promotion of Rural Revitalization of the People's Republic of China	The use of new construction technologies and green building materials in rural housing construction should be encouraged.

6 Conclusion

As a new type of material, cold-formed thin-walled steel is mainly characterized by its lightweight, high strength, good mechanical properties, recyclability, low consumption of steel in the production process, good environmental protection and economy, rich section shapes, and strong adaptability. It has been widely used in the field of prefabricated buildings. The prefabricated cold-formed thin-walled light steel structure building made of cold-formed thin-walled steel has the advantages of earthquake resistance and wind resistance; convenient transportation, short construction period, low cost; green environmental protection, comfort, and energy saving;

various shapes, flexible space and good durability, etc. It is especially suitable for the construction needs of the vast rural areas in China. The cold-formed thin-walled light steel structure buildings are becoming the development trend of rural buildings in the future.

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