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Study on the Dynamic Characteristics of Light Steel Residential Structural System

Wenwei Yang[1,2], Qili Yang[1,2]

[1]Key Laboratory of Mechanics on Disaster and Environment in Western China, the Ministry of Education of China, Lanzhou, China
[2]School of Civil Engineering and Mechanics, Lanzhou University, Lanzhou, China
Email: mlbsabc@sina.com

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Abstract

The study on the dynamic characteristics of light steel residential structural system has both theoretical and practical significance for the application and promotion of light steel residential structural system. In this paper, we analyze several common types of light steel residential structural system, describe the dynamic characteristics of the light steel residential structural system for an overview on the basis of former related studies, and then summarize the advantages of light steel residential structure system.

Keywords

Light Steel Structure, Residential, Dynamic Characteristics

1. Introduction

Since the reform and opening-up policy, people's living standards improve dramatically. After solving problems of the "food" and clothing, people target at "living", and the requirements for "living" are becoming stricter. The living standard has become an important factor for judging a person's living standard. Under the national house-purchase wave, the real estate industry in our country has developed rapidly. From the year of 1996 to 2017, the city and towns residential area in our country increase at an annual rate of more than 1 billion square meters [1]. Under the great demand, the traditional brick housing structure system has become increasingly unable to meet the needs of modern social development, due to its single function, high energy consumption, slow construction speed and worse seismic ability. It becomes an urgent matter to find a new type of housing structure system which is low energy consumption, fast construction speed, good structure performance and reasonable cost price. Steel structure residence comes into being under this background.

At the early days of new China, our nation lacks of steel. Construction steel usage is rare. The proportion of construction steel in the total steel production is extremely low [2]. After the reform and opening up policy, China's steel output reached high record and formed a glut new situation. With the double catalysis of steel overcapacity and residential demand, steel materials used in residential construction become a trend by history. In the year of 1979, China's first steel structure was introduced from Australia [3]. In the year 1966, Ministry of Construction put the "positive, reasonable and fast development of steel structure" as the construction task. In 1999, the state council document No. 72 clearly proposed to develop the steel structure housing industry greatly [4]. And in 2000, the relevant governments stipulated big cities shall not use clay bricks, which pushed many cities to explore new force wall structure and its supporting structure system. In 2003, national foreign trade and economic cooperation committee and State Bureau of Metallurgical Industry worked out together a series of steel structure promotion policy measures. In 2010, the Ministry of Construction has made "Industrial technical guidance of steel structure residential building system" and "Steel frame core tube residential building system technical guidance", put the development and application of steel structure residential structure system as the breakthrough point of construction steel. A large number of steel structure residential pilot projects appeared in our nation, such as the core tube of multi-storey residential steel frame of Beijing Cyber Metal Structure Co., LTD, Shanghai Hongqiao Hotel and Dalian Metallurgy Nursing Home [5].

The development of light steel residential structural system is the epitome of social development in our country. In recent years, although light steel residential structure system has a certain development in our country, to be replicated in further across the country, the light steel residential structural dynamic stability is the precondition of its popularization and application. So, the study on the dynamic characteristics of light steel residential structural system has both theoretical and practical significance. In this paper, we distinguish the several common forms of light steel residential structural system, analyze the dynamic characteristics of light steel residential structure on the basis of former studies, and then summarize the advantages of light steel residential structural system, which provide guidance for the application and promotion of light steel residential structural system.

2. The Classification of the Light Steel Residential Structural System

Light steel is the steel structure which has small component size, light weight and small plus load. Light steel residential structure is the system that uses economical steel components as residential bearing skeleton, light wall materials as envelop enclosure. Economical steel components mainly include cold bending steel, hot rolling or welded h-shaped steel, soldering or seamless tube and its assembly. The commonly used light steel structure system in our country can be divided into five classes according to it's a seismicity, wind resistance and dura-

bility: pure frame structure system, framework-support structure system, the frame shear wall structure system, staggered truss system and steel and concrete composite structure system [6].

2.1. The Pure Frame Structure System

The pure frame structure system is shown in Figure 1. The system is mainly composed of light steel beams and columns. The frame structure has characteristics of flexible layout, large architectural space, uniform stiffness and bid ductility. It is not sensitive to the earthquake and the seismic performance is good. But due to the lateral stiffness of the frame structure is small; the displacement is large under outer loads, which is easy to cause the destruction of the non structural components. So the height of pure frame structure building should not be too high. Generally speaking, in seismically active areas, the pure frame structure buildings should be no more than 15 layers.

2.2. The Framework-Support Structure System

The framework-support structure system is shown in Figure 2. It is a modified structural system aiming at the weakness of large lateral displacement of pure frame structure system. It puts a certain amount of support in the longitudinal and transverse structure system. The arrangement form and structure size of the frame is same with the pure frame structure system. Most supports are set around the center along the floor. Supports along the longitudinal arrangement connect with supports along the horizontal layout and forms a support core barrel. Its stiffness to resist lateral force is bigger than that of the pure frame structure system, and can significantly reduce the displacement between the layers of buildings. The building of the framework-support structure system could be higher than building of pure frame structure system.

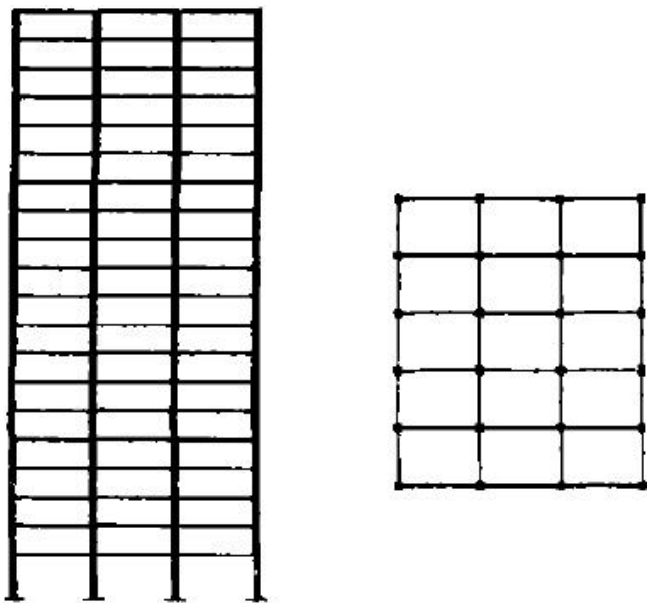

Figure 1. Pure frame structure system.

2.3. The Frame Shear Wall Structure System

The frame shear wall structure system is shown in Figure 3. It puts a certain number of shear walls in the frame structure. This structure uses the shear wall to resist lateral force. It not only has the advantage of the pure frame structure system, but also its lateral stiffness is big, and could be used in tall steel structure buildings of 40 layers to 60 layers. If reinforced concrete wall is set up around the frame service area, then the framework tube structure system could be formed. The stiffness to resist lateral force in all directions of the framework tube structure system is big. The reinforced concrete wall as the major lateral force resisting element bears the most of the horizontal load and steel frame mainly bears the vertical load.

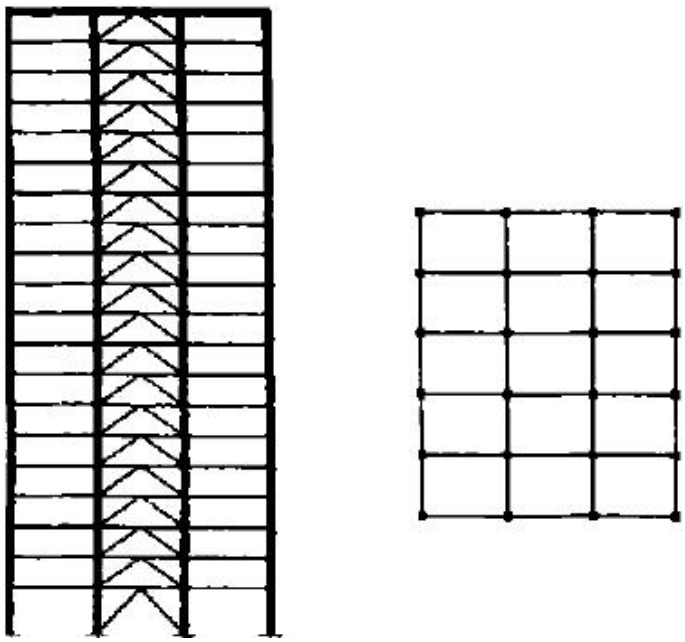

Figure 2. The framework-support structure system.

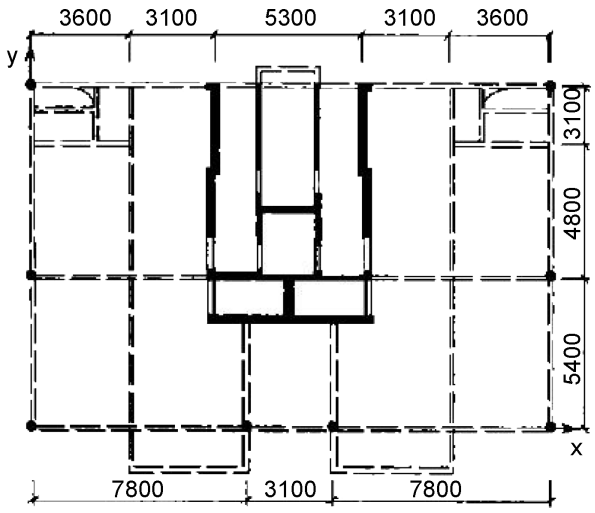

Figure 3. The frame shear wall structure system.

2.4. The Staggered Truss System

The staggered truss system is shown in Figure 4. It is mainly composed of truss and support. The height of the truss is usually one storey high and its full width span is equal to the building. Truss ends are set up in steel columns of building envelope, and the middle column is not set in lateral direction. The supports usually are set in the truss of the lateral columns of buildings at intervals. The truss in adjacent column axis is set in staggered arrangement. Between adjacent trusses, one end of floor is supported in upper chord of the truss, and the other end is supported in the lower chord of adjacent trusses. The staggered truss system is mostly used in the high-rise steel structure residence buildings.

2.5. The Concrete Composite Structure System

The main members of concrete composite structure system are the composite slab, support to resist lateral force, steel reinforced concrete beam, concrete filled steel tubular column and two-way light steel dense composite floor. Floor of the steel and concrete composite structure system is effective to improve the overall structure stiffness and decrease the thickness of the floor. And it is one of the most common residential structure systems nowadays.

3. The Dynamic Characteristics of the Light Steel Residential Structural System

The dynamic characteristics of the light steel residential structural system are usually the natures which will be shown when it bears the external dynamic load. In the practical engineering, the dynamic characteristics of the light steel residential

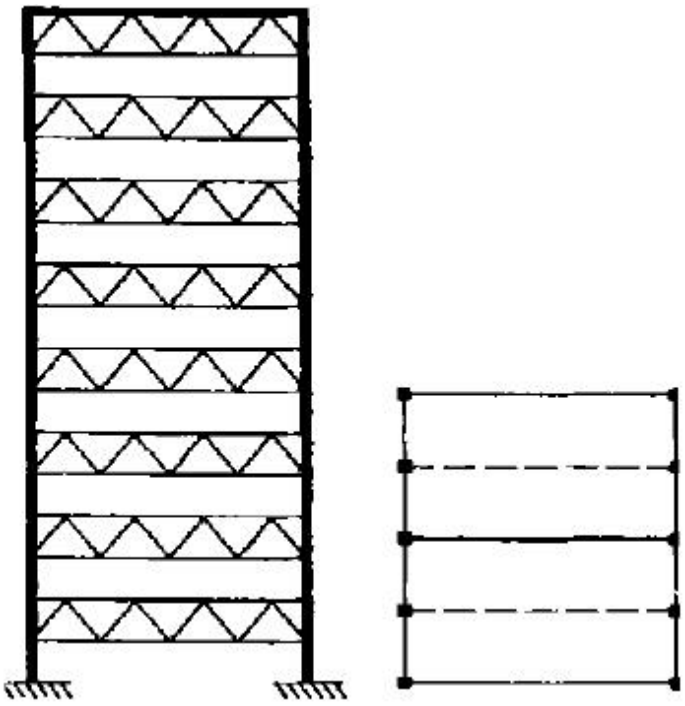

Figure 4. The staggered truss system.

structural system is usually referred to the anti-seismic property. As to the earthquake resistance of the light steel residential structural system, domestic scholars have a lot of work on it.

Wang Fei and others used the modal decomposition response spectrum method, time history analysis, the static elastoplastic analysis method (Pushover method) based on MIDAS finite element software, to analyze the earthquake resistance of the light steel residential structural system, studied the deformation and performance under stress of light steel frame structure, the emergence of the weak layer and failure laws. Their study results show the structure meets the requirements of no damage in small earthquake, repairable under moderate earthquake and no collapse under strong earthquake for seismic resistance [7].

Zou Yun and others use ANSYS and SAP2000 to analyze the self-vibration characteristics of the frame supporting structure system in three different supporting forms of X form, V form and herringbone form, and did time-procedure analysis of elastoplasticity under effects of the rarely and frequently met earthquakes by typing El-Centro wave and Shanghai artificial wave. They discussed the dynamic characteristics and seismic response of structure of different forms of support structure system. The results show the support effects of herringbone form and V form are similar, and their structural stiffness is higher than the frame supporting structure system in X form [8].

Chu Mingjin and others studied the mechanical properties and failure mechanism of failure mode, hysteretic characteristics, ductility and rigidity degeneration by pseudo static test of reinforced concrete composite structures under the horizontal repeated loading. The studies show reinforced concrete composite structures have higher bearing capacity and better ductility in multi-storey residential structure. Putting steel into the wall can significantly increase the ductility and bearing capacity of the wall [9].

Liu Jinghua and others analyze and compare the dynamic characteristics of the pure frame structure system, framework-support structure system and the frame-core tube structure by using ANSYS finite element software. Results show the lateral resisting abilities of three types of residential structure system are: the frame-core tube structure is better than framework-support structure system and framework-support structure system is better than pure frame structure system. Under the action of the earthquake, the interlayer displacement angle of pure frame structure system is beyond the limit and its seismic performance is the worst. But because of the flexible space layout of pure frame structure system, its getting a house rate is high in the housing industry. The pure frame structure system is generally applied in lower layers buildings (six layers or less) and middle and low intensity (8 degrees and less) of the light steel housing. The anti-seismic property of framework-support structure system is slightly better than that of pure frame structure system, and it has good ability of energy consumption and is applied multi-storey and middle and high intensity of the light steel house buildings. The anti-seismic property of frame-core tube structure is the best. When the depth-width ratio of shear wall of core tube is bigger than 4,

it will show a certain energy consumption. Considering the earthquake-resistance and economical factor, the frame-core tube structure is more suitable for high-level and high intensity of the light steel house buildings [10].

4. The Advantages of Light Steel Residential Structure System [11]

Compared to the traditional civil building structure, the light steel residential structure system is a new form of residential buildings, and it has following outstanding features.

4.1. The Light Steel Residential Structure Has Light Weight, High Intensity and Good Seismic Performance

The light steel structure use lightweight steel as the main bearing component of residential structure, and its structure weight greatly decreases compared to the traditional brick structure. Besides, because the strength and stiffness of steel are higher than the traditional brick structure, so the strength and seismic performance of the light steel structure housing are better than that of traditional brick structure.

4.2. Construction Speed Is Quick and Investment Recovery Is Faster

Light steel structure can be prefabricated in a factory and doesn't need to cast-in-place. Light steel structure components only need the simple bolts and rivets lock or soldering. So, its construction technology is simple, assembly degree and mechanization degree are high, and it is affected by external environment little. As a result, the speed of light steel residential structure is much faster than the traditional brick structure and reinforced concrete structure, and payback period of construction projects is short, so money can be quickly drained and investment return is high.

4.3. It Is Easy for Large-Scale Production

Light steel structure components can be made and processed in large-scale in professional factories and doesn't need fabrication on site. The scale of production is not restricted by field condition, and can be produced in large-scale mechanization and industrial production.

4.4. Architectural Space Decorations Are Varied

Due to the good bearing performance of the steel, light steel structure can arrange a larger space, a long span or big column spacing in the construction plane flexibly. The layout scheme is varied and functions are complete.

4.5. It Is Environmentally Protected and Energy Saving

Most of the materials of light steel structure can be recycled. Its construction is simple, because it only needs to assembly simply. And the noise and dust caused in

construction procedure are little. So it has little influence on surrounding environment, which meets the requirements of building an environment friendly society.

4.6. The Fireproof Performance Is Good

Light steel structure use a lot of light steel, so its fireproof performance is better than that of the traditional brick structure and reinforced concrete structure.

5. Conclusion

The light steel residential structure system is a new type of residential construction modes, which has a broad market application prospect. In this paper, we describe the characteristics of most commonly-used light steel residential structure system. On the basis of former studies, we express the dynamic characteristics of light steel residential structure system in general and summarize the advantages of it, which as a result, provides some certain reference values for the application and development of light steel residential structure system. However, the light steel residential structure system also has shortcomings, for example, the cost is likely to be high because there is no great demand in China now, but this will improve in the future.

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