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A review on mechanical properties of cold-formed thin-wall steel-reconstituted bamboo composite beams

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Abstract

In recent years, the rapid development of our country's economy, the scale of the building industry has expanded even more, and the technology has improved significantly and the strength has improved obviously. Construction as one of the four key areas of energy conservation and emission reduction, its energy consumption and emissions have been high, in accordance with the national strategic objectives of sustainable development decree, prosperous environmental protection construction, promote energy conservation and emission reduction in the construction field urgent. China has vast resources and a large population. Since ancient times, China has been carrying out housing construction. In recent years, with the continuous updating of China's smelting process and the continuous increase of steel production, under the background of China's sustainable development road, the combination of cold-formed thin-wall steel and bamboo has changed China's traditional housing construction mode, and promoted modern science and technology housing, which has an important role and significance for promoting the progress of industrial housing. Steel-bamboo combination structure in China's construction industry in the future will enter a new period of progress, this structure in the scope of use and development situation will be more broad.

Keywords

Dual carbon; Cold-formed thin-walled steel; Recombinant bamboo; Combination.

1. Introduction

In recent years, the scale of China's construction industry has expanded, the technology has improved significantly, and the strength has improved significantly. As one of the four key areas of energy saving and emission reduction, the energy consumption and emissions of buildings have been high. In order to respond to the call of the national sustainable development strategic objectives, it is urgent to develop environmentally friendly construction and promote energy saving and emission reduction in the construction field. With the continuous updating of China's smelting process and the continuous improvement of steel quality, China has become a powerful country in steel industry. With unique advantages of raw materials, the application range of steel structure is more and more extensive. Cold-formed thin-wall steel structure system has a variety of applications in China, the structure has small weight, good seismic performance, flexible and diverse cross section forms, easy to process, and the building materials are environmentally friendly and recyclable, so it has a wide range of applicability[1]. As the original product of our country, bamboo has many types, strong adaptability and wide distribution. Moreover, the raw materials are convenient to obtain, the price of the raw materials is low, the ripening time is short, and the material is a superior building raw material. Under the background of sustainable development in China, the combination of cold-formed

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thin-walled steel and bamboo can change the traditional residential construction mode in China. It plays an important role in the development of modern housing of Science and Technology and industrialized housing. Steel-bamboo composite structure will enter a new period of progress in China's construction industry in the future, and this structure will have a broader scope of use and development situation.

2. Research background

Since the 21st century, China has called for the strategy of sustainable development. The production process of ordinary reinforced concrete structures has caused serious pollution, and the use of non-renewable raw materials has released a large number of greenhouse gases, resulting in serious energy pollution. Cold-formed thin-walled steel is a lightweight structure with small deadweight, recycling, excellent physical properties and excellent seismic capacity, which has caused a wave of exploration in scientific research[2]. Reconstituted bamboo is a kind of renewable energy, strong growth ability. The combination of the two can greatly improve the carrying capacity of the structure.

2.1. Advantages and characteristics of cold-formed thin-wall steel

In recent years, with the proposal of the national sustainable development strategy, green and recyclable use has been advocated by the state. As a booming construction raw material, cold-formed thin-walled steel has many advantages[3]:

1) Cold-formed thin-walled steel has smaller dead weight, higher bearing capacity and larger overall stiffness. Compared with the traditional building structure, its dead weight can be reduced by 20 ~ 30%, and the size of the structural section can be obviously reduced, thus reducing the production cost. Cold-formed thin-walled steel has good ductility, so the overall seismic grade is higher. In addition, there is less demand for building foundations, which is a significant advantage in soft soil areas.

2) The production cycle of cold-formed thin-walled steel members is short, which can be processed in the workshop and directly spliced and installed on site, effectively improving the construction progress, so that the project can be put into operation as soon as possible.

3) The section has high cost performance and can be recycled continuously. The correct component section with the most efficient stress distribution can be constructed according to the actual construction requirements, and the recovery, processing and reuse can be carried out according to the call of the national sustainable development strategy.

4) The strength limit of cold-formed thin-walled steel structure is relatively high. The cold-formed thin-walled steel structure is produced by the material through cold bending treatment, and the cold bending effect will be produced during the treatment process, which mainly appears in the increase of the yield strength of the bending part.

2.2. Advantages and characteristics of reconstituted bamboo

In recent years, the supply of superior quality wood materials, especially hardwood, has been decreasing, and the market price has been increasing. This leads to the aggravation of the conflict between supply and demand in the market of such materials. In order to deal with this conflict and make use of the convenient bamboo resources in southern China, reconstituted bamboo came into being. Reconstituted bamboo has many advantages[4]:

1) Reconstituted bamboo has light weight, high strength and excellent mechanical properties. In the case of loading the same load, the weight of reconstituted bamboo is lighter than that of other woods, so that the construction of houses can minimize the building's own weight and bear the role of load in the construction industry.

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2) Reconstituted bamboo has excellent earthquake resistance, excellent toughness and good elastoplasticity. In the area of high incidence of earthquakes, the use of this material can greatly reduce the damage to the building structure caused by the earthquake, and can increase the safety factor of the building.

3) Reconstituted bamboo raw material is convenient, low price, short growth cycle. Bamboo in southern China is rich in raw materials, strong renewable ability, easy to grow, and easy to be degraded by nature, does not pollute the environment.

4) Factory processing can be carried out, and on-site assembly can be connected to reduce the construction time and speed up the process of the construction period.

3. Research status at home and abroad

3.1. Domestic research status of cold-formed thin-wall steel

In 2017, Nie Shaofeng[5] used screws to connect C-shaped and U-shaped components to columns with closed sections and conducted axial compression tests to explore the axial compression performance of the structure. The buckling form and damage characteristics of the structure were analyzed and the conclusion was drawn that in the axial compression test, the damage form of the long column type components was the overall bending damage around the weak axis of the structure. In addition, the finite element simulation analysis shows that the ultimate axial compression load and stiffness of the structure are sufficient to decrease with the increase of the length of the specimen and the width of the web.

In 2017, Tang Hongyuan'research results[6] show that the failure form of the component during the axial compression loading test is the overall bending and torsional instability, and the stable bearing capacity of the structure after bonding is increased in different ways compared with that of ordinary specimens. And when the interval distance of CFRP and the overall height of the web is less than 1, the strengthening effect is the best, and the strengthening effect of both sides of the adhesive is better than that of the first layer. Finally, the finite element software was used to establish the model and carry out numerical simulation analysis. The actual results were in good agreement with the software simulation results.

In 2018, Yin Dongxiong[7] conducted an axial compression test on 32 cold-formed thin-wall steel spliced double-limb box structural columns to analyze the axial compression performance of the structure, focusing on the mechanical properties, damage forms and change characteristics of the double-limb spliced box structural columns, and explored the influence of the structure's slenderness ratio and height-thickness ratio on the stability of the structure. In the end, the numerical calculation formula was revised.

3.2. Foreign research status of cold-formed thin-wall steel

Wilson[8] conducted an experimental investigation by using the axial compression method for the two C-section jointed members, focusing on the effect of welding distance and boundary conditions on the bearing capacity of the structure. The experimental investigation showed that when the welding distance between the structures was less than 600mm, the slenderness ratio of the structural split section could ignore the effect of the connecting distance between the members. When the distance between the welding structures is 900mm, the limit condition has the greatest effect on the bearing capacity of the structure. Therefore, for the connection method of welding between structures, only when the distance is less than 600mm, it is not necessary to revise the slenderness ratio of the split section.

Zhang[9] adopted axial compression, eccentric compression test and finite element analysis on the stainless steel columns of the same category with different thicknesses and different slenderness ratios of high-strength cold-formed thin-wall steel split box section. The test conclusion shows that the column of the spliced box structure will be damaged under the

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common interference of local deformation, distortion deformation and overall deformation. On the basis of the good agreement between the finite element model and the test results, a lot of data are used to analyze and explore the interference to the ability of the splicing column. Finally, the finite element calculation results are compared with the current standard theory results, which shows that the standard calculation values tend to be conservative, and points out the design calculation formula of the splicing section column. H.R.Naderian and H.R. Ronagh[10] A key characteristic of this method, in contrast to the usual finite strip method, is that it can deal with the shear effects arising from the use of the complex function method. In addition, a composite finite strip method is proposed to investigate the distortion and local and global deformation of cold-formed thin-wall steel.

3.3. Research status of cold-formed thin-wall steel-reconstituted bamboo composite structure

In 2015, Zhang Xiuhua[11] elaborated the characteristics of reconstituted bamboo, cold-formed thin-wall steel and steel-bamboo splintering members, explained the changes and recent use of these three types, and proposed that green recyclable and reusable steel-bamboo splintering members have strong advantages under the general situation of calling for the development of green energy-saving and emission-reduction construction industry, as shown in Fig. 1.

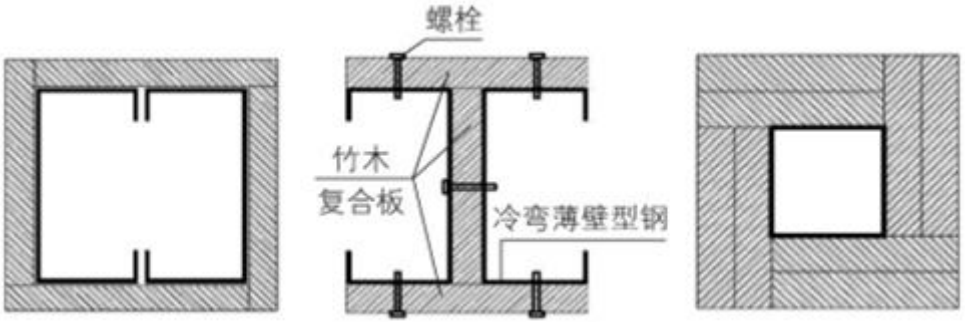

Fig.1 Steel-bamboo composite bamboo section form

In 2018, Ge Yumeng[12] pointed out the better splicing effect of steel-bamboo splicing I-beams, combined cold-formed thin-wall steel and reconstituted bamboo with epoxy resin glue or epoxy resin glue and self-tapping screws to form the composite. Taking the shear span ratio, section steel height, web thickness and height of the components as variables, the shear performance test was carried out on 12 splicing beams, and the damage process and change characteristics of the splicing beams were observed, as well as the interference variables of the shear bearing capacity of the components were analyzed, and it was pointed out that the theoretical method of the shear bearing capacity of the splicing beams had a high shear bearing capacity. The primary factor that interferes with the shear bearing capacity of the splicing beam is the shear span ratio. When the shear span ratio increases, the damage characteristics of the composite beam gradually change from shear damage to bending damage; It is also pointed out that the conclusion of the theoretical method of the shear bearing capacity of the spliced beam is in good agreement with the experimental data. In 2020, MAO Ming[13] pointed out that the cold-formed thin-wall steel was bonded with reconstituted bamboo and bamboo plywood with epoxy resin to form a I-beam splicing beam, taking the thickness of the bamboo plate, the height of the section of the member, the wall thickness of the cold-formed thin-wall steel and the width of the flange as variables, and using the bending performance test for the two types of members. Conclusion The two types of steel and bamboo splicing beam members have excellent overall working ability, excellent splicing effect, high bearing capacity and excellent ductility. The damage state of cold-formed thin-wall steel-reconstituted bamboo is relatively simple, which is very varied compared with that of cold-formed thin-wall steel-bamboo plywood splicing beam. The flexural bearing capacity of the spliced beam is actually related to the physical properties, and when the thickness of the bamboo plate, the section height of the structural beam, the wall

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thickness of the cold-formed thin-wall steel and the width of the flange are increased, the bearing capacity of the member is significantly improved, and the span of the cold-formed thin-wall steel-bamboo spliced beam is obviously larger than that of the cold-formed thin-wall steel-reconstituted bamboo spliced beam under the same circumstances. The production process is shown in Fig.2.

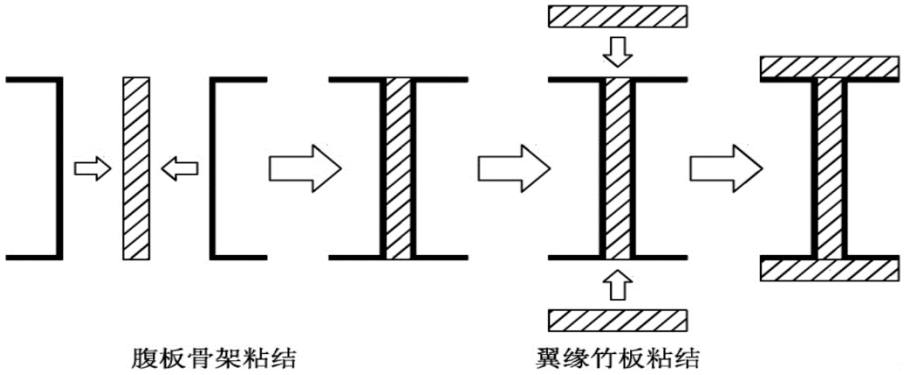

Fig.2 Fabrication process of I-section composite beam

In 2022, Miao Qiliang[14] designed three spliced columns with different sections by exploring the damage forms and ultimate bearing capacity of the spliced cold-formed thin-wall steel strip flanged cross section specimens under axial load, and used the finite element software ABAQUS to simulate the components with different sleneness ratios and screw spacing. The results show that the slenderness ratio of the member affects the instability mode, and the impact of the splicing action on the torsional buckling capacity of the splicing column is more significant than that of the flexural buckling capacity.

4. Epilogue

Under the background of China's sustainable development, steel structure construction has set off a wave in our country, but a key reason to constrain the progress of steel structure is the stability of steel structure, cold-formed thin-wall steel members are prone to buckling, instability damage, through the combination of cold-formed thin-wall steel and bamboo, can achieve the bearing capacity of members in the case of minimum steel use, In line with the requirements of green energy saving building, has practical guiding significance for the project. It has changed China's traditional housing construction mode and promoted modern science and technology housing, which plays an important role and significance in promoting the progress of industrial housing. The steel-bamboo combination special-shaped column structure connects the architectural beauty, the flexibility of the use function and the reasonable mechanical performance of the building structure, and provides an excellent living environment for the majority of residents. In our country's construction industry in the future will enter a new period of progress, this structure in the use of the scope and development situation will be more broad.

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