

# ***Development of Steel Structures in the Context of Carbon Peaking and Carbon Neutrality***

Rui Qin<sup>1,a,\*</sup>

<sup>1</sup>Henan Polytechnic University, No. 2001 Century Avenue, Shanyang District, Jiaozuo City, Henan Province, China

a. 410301021@qq.com

\*corresponding author

**Abstract:** This paper discusses the current development status and future trends of the steel structure industry in the context of peak carbon and carbon-neutral targets. Through literature review and data analysis, it highlights the steel structure's benefits in energy saving, emission reduction, and resource recycling. And puts forward strategies and suggestions to promote the development of the steel structure industry. The results of the study show that the steel structure industry plays an important role in coping with climate change and realizing green and low-carbon development, and policy support and technological innovation should be increased in the future to promote the healthy development of the steel structure industry.

**Keywords:** carbon peak, carbon neutral, steel structure, green development, energy saving and emission reduction.

## **1. Introduction**

With the increasingly serious problem of global warming, reducing greenhouse gas emissions and achieving carbon peak and carbon neutrality have become the common goals of the international community. As one of the major fields of energy consumption and carbon emission, the green and low-carbon transformation of the construction industry is particularly important. As an environmentally friendly, energy-saving, and recyclable form of building structure, steel structure has ushered in unprecedented development opportunities against the backdrop of peak carbon and carbon-neutral targets[1]. This means that the construction industry is facing the pressure and opportunity of a low-carbon transition, which will further drive the optimization and development of the steel structure industry. This paper aims to discuss the development status and future trends of the steel structure industry, providing theoretical support and practical guidance for promoting the green and low-carbon development of the construction industry.

## **2. Literature Review**

### **2.1. Development of steel structures**

It has gone through three stages: the classical theory of permissible stress, which treats the material as an elastomer; the ultimate strength theory, which takes into account the plasticity of the material;

and the theoretical system of designing according to the limit state[2]. In addition to this, research into the materials and structural forms of steel structures is constantly evolving.

## **2.2. Low carbon building**

Low-carbon buildings are buildings that reduce carbon dioxide emissions by reducing fossil energy use and improving energy efficiency throughout the life cycle of building materials and equipment manufacture, construction and building use[3]. This concept emphasizes the commitment to reducing carbon emissions throughout the life cycle of a building, from design, selection of building materials, construction to operation and maintenance. The planning and design phase, as the starting point of the building's entire life cycle, plays a crucial role in the carbon emissions of the building[4]. With the increasing global concern for climate change and sustainable development, low-carbon buildings have gradually become an important direction for the development of the construction industry.

## **2.3. Steel Structures in China**

In recent years, there has been a gradual increase in research on the application of steel structure in the construction industry and its environmental performance. Scholars at home and abroad generally agree that steel structure has the advantages of being lightweight, high strength, fast construction speed, and recycling, and have a wide application prospect in the construction industry. At the same time, the steel structure also shows significant advantages in energy saving and emission reduction, resource recycling, and other aspects. With the support of national policies, the steel structure industry has developed rapidly[5].

## **2.4. The gap between China's steel structure and that of developed countries**

There are several gaps between steel structures in China and those in developed countries. Firstly, in terms of application share, the proportion of steel used in steel structure in China is only about 8 per cent of the overall steel production, which is far lower than the proportion of more than 30 per cent in most developed countries. Secondly, the proportion of steel structure in important infrastructures, such as key buildings and municipal highways and bridges, is less than 1 per cent, whereas in developed countries, the proportion of steel structure in these areas is as high as 30 to 40 per cent. Furthermore, China still relies on imports of steel for high-rise buildings, especially for thick steel plates larger than 50mm, and the performance of domestic products is not yet up to the requirements. Finally, although China has made significant progress in special steel, such as super steel, but in the overall level of technology and product quality, compared with the United States, Japan, Germany and other developed countries there is still a certain gap.

## **3. Methodology**

Using a blend of literature analysis, data analysis, and case study methodology, this study aims to provide an all-round in-depth discussion on the current development status and future trends of the steel structure industry. In this process, firstly, we systematically understand the development history and current situation of the steel structure industry by extensively reviewing relevant literature and policy documents. This allows us to grasp the industry as a whole at a macro level.

Secondly, we actively collect and meticulously collate statistical data on the steel structure industry. Through in-depth analyses of these data, we can accurately assess its actual performance in key areas such as energy conservation, emission reduction, and resource recycling.

Finally, we combine representative typical cases to discuss in depth the unique advantages of the steel structure industry in coping with climate change and realizing green and low-carbon

development, as well as the many challenges it faces. The introduction of case studies makes our study more realistic and relevant and helps us put forward practical suggestions and countermeasures from the practical operational level.

## **4. Results**

### **4.1. Development status of the steel structure industry**

In recent years, China's steel structure industry has been developing rapidly, and its output and scale have been expanding. According to statistics, so it is necessary to pay attention to improving the efficiency of steel utilization and reducing steel consumption[6]. China's steel structure production has maintained high growth for many years, becoming one of the largest steel structure producers in the world. At the same time, the application scope of steel structures in the field of construction is also expanding, gradually expanding from traditional industrial plants, warehouses, and other building types to high-rise residential and commercial complexes.

### **4.2. Performance of steel structure in energy saving and emission reduction**

The steel structure has significant advantages in energy saving and emission reduction. Firstly, steel structure buildings can reduce a large amount of solid waste, energy consumption, and water consumption during the construction process, thus reducing carbon emissions (Compared to concrete buildings, steel buildings reduce carbon emissions by 15 per cent, dust by 59 per cent and solid waste by 51 per cent during the manufacturing and construction phases, as well as saving 12 per cent in energy consumption and 39 per cent in water use). Secondly, steel structure buildings have good heat preservation and insulation properties during use, which can reduce energy consumption and operating costs. In addition, steel structure buildings can also achieve efficient recycling of materials when dismantled, reducing resource waste and environmental pollution.

### **4.3. Challenges and Opportunities for the Steel Structure Industry**

China's steel production has jumped to the top of the world and is still increasing. The application of steel structures will also have greater development, but it still faces some challenges[7]. Issues such as insufficient policy support, insufficient technological innovation, and low market awareness have constrained the further development of the steel structure industry. However, against the backdrop of peak carbon and carbon-neutral targets, the steel structure industry is also presented with great development opportunities. The government will increase its support for green building and energy-saving and environmental protection technologies, and promote the transformation of the construction industry in the direction of green and low-carbon. At the same time, as society's awareness of environmental protection increases and the concept of green building becomes more popular, the steel structure industry will usher in a broader market space.

### **4.4. Carbon Emissions in China's Construction Industry**

In terms of total volume, the total energy consumption of the country's buildings and construction in 2020 was 2.27 billion tonnes of standard coal, and the total carbon emissions were 5.08 billion tonnes of carbon dioxide. By 2021, the total energy consumption of the whole process of the country's buildings (including the use of building materials in buildings and infrastructure, building construction, and building operation) will grow to 2.35 billion tonnes of standard coal, with total carbon dioxide emissions of 5.01 billion tonnes[8]. The total amount of carbon emissions has declined slightly and the share of total national carbon emissions has also declined.

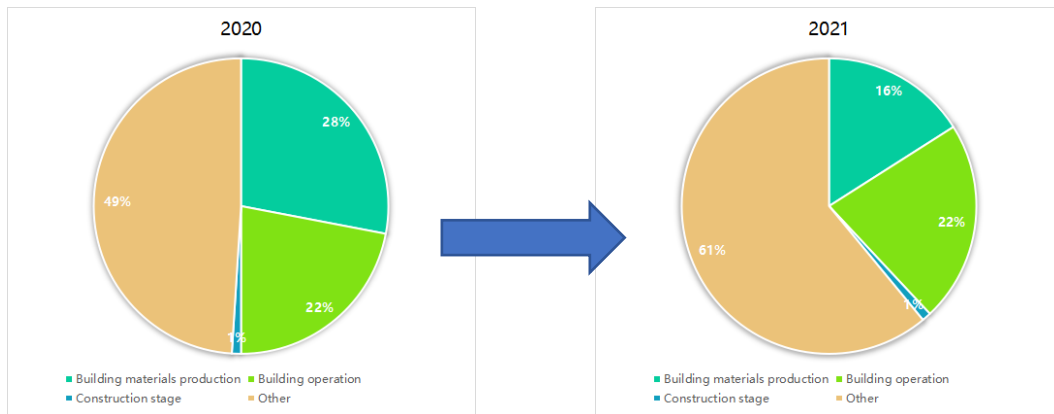


Figure 1: Changes in Carbon Emissions from China's Construction industry

Although some progress has been made, carbon emissions in China's construction sector remain a serious problem.

#### 4.5. Advantages of steel structures in terms of carbon emissions

Compared with traditional concrete structures, steel structures have relatively low carbon emissions from production, transport, and installation. At the same time, the long service life and high re-usability of steel buildings further reduce their full life cycle carbon emissions.

The main advantages are as follows:

**Advantage at the building material production stage:** Steel buildings have lower carbon emissions during the material production process compared to traditional concrete structures. According to the research of professional organizations, steel structure houses use 100kg to 120kg of steel per square meter of building, and their carbon emission is 480kg/m<sup>2</sup>, while the carbon emission of building materials for concrete structure houses is 740.6kg/m<sup>2</sup>. This means that the carbon emissions of steel-framed houses are about 35 percent lower than those of concrete structures.

**Advantages in the building construction phase:** Carbon emissions in the building construction phase are also relatively low because the components of steel buildings can be prefabricated in factories, reducing on-site wet work. This prefabricated and assembled construction method not only improves construction efficiency but also helps to reduce energy consumption and waste generation during construction.

**Advantages of the building dismantling and recycling phase:** Steel-framed buildings are relatively easy to dismantle and most of the materials can be recycled. In contrast, concrete structure buildings are difficult to dismantle, have a low recycling rate, and are prone to generating large amounts of construction waste. The high recycling rate of steel structures helps to reduce resource waste and environmental pollution.

**High potential for energy saving and emission reduction:** steel structure buildings have advantages in heat preservation, insulation and ventilation, etc. By optimizing building design and adopting advanced energy-saving technologies, the energy consumption and carbon emission of the building during the operation phase can be further reduced.

## 5. Discussion

### 5.1. Suggestion

Given the development status quo and the challenges and opportunities faced by the steel structure industry, this paper puts forward the following suggestions: firstly, to strengthen the policy support

and formulate clearer development plans and policy measures for green building and steel structure industry; secondly, to strengthen the technological innovation and talent cultivation, and to improve the core competitiveness and sustainable development capability of the steel structure industry; The third is to strengthen market publicity and promotion to improve the recognition and acceptance of steel structure buildings in all walks of life. In addition, the steel structure industry should also actively explore new application fields and market space, such as assembly building, bridge engineering, marine engineering, and other fields, to expand its application scope and market share. At the same time, the steel structure industry should also strengthen collaboration and cooperation with upstream and downstream industries to form a complete industrial chain and value chain and improve the competitiveness and profitability of the whole industry.

## **5.2. Method settle an issue**

### **5.2.1. Ways to Strengthen Policy Support**

Defining development goals: Firstly, development goals for the green building and steel structure industries need to be set, including increasing the proportion of green buildings, promoting the proportion of steel structures used in various types of buildings, and upgrading the technical level of the industry. These targets should be measurable so that the effects of the policies can be assessed.

Formulation of special policies: To address the characteristics and needs of the green building and steel structure industry, special policy documents have been formulated, including policy measures on tax incentives, financial support, and land supply. These policies are aimed at encouraging enterprises to increase the research, development, and application of green building and steel structure technologies and promote the transformation and upgrading of the industry.

Improvement of regulations and standards: Establish a sound system of regulations and standards for green buildings and steel-framed buildings, clarifying design requirements, construction norms, acceptance standards, and so on. This will help to ensure building quality and safety while promoting the industry to a higher level of development.

Strengthening regulation and law enforcement: Establishing a sound regulatory mechanism and strengthening the supervision and inspection of green building and steel structure projects to ensure that policy measures are effectively implemented. For violations of policy provisions, penalties will be imposed in accordance with the law to form an effective deterrent.

Promoting demonstration projects: Select representative green building and steel structure projects as demonstrations, demonstrate their advantages and achievements through publicity and promotion, experience sharing, etc., and guide more enterprises and projects to adopt green building and steel structure technologies.

Strengthening international cooperation and exchanges: Drawing on international advanced experience and technology, strengthening exchanges and cooperation with the international green building and steel structure industry, promoting China's green building and steel structure industry to meet international standards and enhancing international competitiveness.

Strengthening publicity, education, and training: Strengthening publicity, education, and training on green building and steel structure technologies by organizing training courses, seminars, exhibitions, and other activities, to increase the awareness and acceptance of green building and steel structure among all sectors of the society.

### **5.2.2. How to Strengthen Technological Innovation and Talent Training**

Technological innovation:

**Research and development of energy-efficient technologies:** Research and development of new energy-saving materials, such as building materials made from renewable resources, to reduce carbon emissions.

**Promote and apply energy-efficient air-conditioning systems, lighting systems, etc.,** to reduce building energy consumption.

**Upgrade building design and construction techniques:** Use advanced building design software to optimize building layout and structure and reduce energy waste. Introduce advanced construction technologies, such as prefabricated assembly building technology, to improve construction efficiency and quality.

**Strengthening the application of intelligent technology:** Using the Internet of Things, big data, and other technologies to achieve real-time monitoring and management of building energy consumption and optimize energy use. Research and development of intelligent building management systems to improve the intelligent level of building operation and maintenance.

**Talent development:**

**Establishment of a professional personnel training system:**

Colleges and vocational schools should set up specializations or courses related to low-carbon steel structure construction to cultivate talents with relevant knowledge and skills. Establish internship and practical training bases to provide students with practical opportunities and enhance their practical skills.

**Strengthening cooperation between industry, academia, and research:** Promote cooperation between enterprises universities, and research institutions to jointly carry out technology research and development and talent training programs. Encourage enterprises to set up scholarships and bursaries to support outstanding students to complete their studies and devote themselves to the cause of low-carbon steel structure construction.

**Professional training and education:** Organize professional training for practitioners regularly to update their knowledge and skills to meet the development needs of low-carbon steel buildings.

Organize activities such as forums and seminars to share the latest developments and technical achievements of the industry and promote the exchange of experience.

**Establishment of an incentive mechanism:** Recognize and reward talents who have made outstanding achievements in the field of low-carbon steel structure construction to stimulate their enthusiasm and enthusiasm for innovation. Provide a good career development platform and promotion opportunities to attract more talents to join this field.

### **5.2.3. Ways to enhance market communication and outreach**

**Strengthen brand image and market positioning:** Clear market positioning is the key to promotion. Low-carbon steel structure enterprises should clarify the positioning of their products in the market, such as the high-end market, mid-range market, or specific application areas, such as green buildings, energy-saving buildings, and so on. Establish and strengthen the brand image, highlighting the characteristics of low-carbon steel structures such as environmental protection, high efficiency, and durability, so that consumers can quickly recognize and have a sense of trust.

**Use diversified publicity channels:** Make use of traditional media, such as TV, radio, newspapers magazines, etc., to carry out advertising to expand brand awareness.

Make full use of the Internet and social media platforms, Such as Weibo, WeChat, TikTok, and so on, to carry out online promotion, interact with the target customer base, and increase brand exposure. Organize or participate in industry exhibitions, forums, and other events to showcase the advantages and application cases of low-carbon steel structures and attract the attention of potential customers and industry partners.



**Strengthen cooperation and alliances:** Establish close partnerships with architectural design institutes, property developers, construction units, and other relevant industries to jointly promote the application of low-carbon steel structures in the construction sector. Seek cooperation with government, industry associations, and other organizations for policy support and industry promotion opportunities.

**Build cases and demonstration projects:** Create representative cases of low-carbon steel structure buildings to demonstrate their advantages in energy saving, emission reduction, environmental sustainability, and other aspects. Participate in or build demonstration projects to demonstrate the performance and application effect of low carbon steel structure through actual projects, and enhance the confidence and recognition of the market.

## 6. Conclusions

This paper provides an in-depth and comprehensive discussion of the development of the structural steel industry in the context of peak carbon and carbon neutrality targets. The results of the study clearly show that the steel structure industry has a key and important role to play in combating climate change and realizing green and low-carbon development. Specifically, the importance of the steel structure industry is mainly reflected in the following aspects. Firstly, steel structure has the advantages of high strength, lightweight, and fast construction speed, which can effectively reduce the consumption of construction materials and energy waste, and reduce carbon emissions. Secondly, the wide application of steel structures can help promote the development of construction industrialization and assembly building and improve the quality and efficiency of construction projects. Thirdly, steel structure buildings have good energy-saving effects in the process of use, which can reduce the energy consumption of building operations.

To promote the vigorous and healthy development of the steel structure industry and provide solid and powerful support for the green and low-carbon transformation of the construction industry, we can take a series of measures. Firstly, policy support should be increased, including financial subsidies and tax incentives, to enhance the enthusiasm of enterprises to participate. Secondly, the innovation of technology should be strengthened, for example, in terms of materials, high-performance materials can be further developed and applied to improve the strength and durability of the building; in terms of design and construction, digital design and intelligent manufacturing can be adopted to improve design accuracy and construction efficiency, As well as the application of green materials and so on. Finally, the promotion of the market needs to be strengthened to increase public awareness and acceptance of steel structures.

With the continuous improvement of environmental protection awareness throughout the whole society and the widespread popularization of the green building concept, the steel structure industry is bound to usher in broader development prospects and opportunities. On the one hand, the steel structure industry is expected to be more widely used in the construction field and become an important support for the transformation and upgrading of the construction industry. On the other hand, the development of the steel structure industry will also drive the synergistic development of related industries, creating more economic value and social benefits.

However, the steel structure industry is also facing some challenges, such as higher costs and imperfect technical standards. The higher cost of steel structure can be solved by the following aspects: firstly, through design optimization, such as reasonable selection of structural form, refinement of design, reasonable use of space, etc., the amount of material and the weight of the structure can be effectively reduced, so as to lower the cost of manufacturing and transportation. Secondly, reasonable selection of materials, fully consider the performance, use and price of materials, choose reasonable price and excellent performance of materials, is also the key to reduce costs. Furthermore, improving construction efficiency, adopting advanced construction technology and equipment, and reducing the

waste of human and material resources can further reduce costs. Finally, cost reduction can also be achieved by recycling and replacing traditional materials. For imperfect technical standards, steel structure enterprises should continuously improve their competitiveness, strengthen industry self-discipline, and jointly promote the sustainable development of the steel structure industry.

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